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# LONG LENGTH CUTTINGS FROM NO. 2 COMMON HARDWOOD LUMBER

by Edwin L. Lucas

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WARREN T. DOOLITTLE, DIRECTOR

## The Author

EDWIN L. LUCAS received his bachelor of science degree in forest products from Colorado State University in 1961, and his master's degree in forest economics from Iowa State University in 1967. At present he is an associate wood technologist in the Station's hardwood product improvement project at the Forest Products Marketing Laboratory at Princeton, West Virginia.

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# LONG LENGTH CUTTINGS FROM NO. 2 COMMON HARDWOOD LUMBER


## Abstract

Long length cuttings (up to 60 inches) are obtainable in abundance from No. 2 Common oak lumber. Cutting for the maximum area of clear one face (C1F) parts 18 to 60 inches in length, we found that 46 percent of all the cuttings were 36 inches long or longer. The recovery of the long length cuttings did not reduce the overall yield of parts produced from the lumber. Computer simulation of conventional rough mill practices was based on a detailed analysis of 4,500 board feet of No. 2 Common oak lumber.

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## INTRODUCTION

SHOULD YOU use No. 2 Common hardwood lumber for dimension cuttings that are longer than 40 inches? The industry generally says "no", but we believe the right answer may be "yes". With current practice, a load of lumber is sawed for a specified order which contains a limited number of cutting sizes. Processing is done quickly, and the memory and judgment of the saw operator are important. A 40-inch length limit is accepted as a maximum for No. 2 Common.

What is commonly done and what is possible are not always the same. To find out what is possible, we used computer simulation to analyze over 4,500 board feet of No. 2 Common oak lumber. We found that it is possible to get a substantial volume of 40-inch and longer clear one face (C1F)[1] cuttings from No. 2 Common boards. Our results represent the optimum yield; how close a mill approaches this optimum will depend on the skill and efficiency of its operators.

[1]"Clear one face" as defined by National Hardwood Dimension Manufacturers Association shall be clear one face, both edges and both ends, and may contain defects of a sound nature on the reverse side.

## THE STUDY

Our computer simulation study is an extension of work done by the Forest Products Laboratory (FPL) in Madison, Wisconsin *(1, 2, 3, 4)*. From their work you can determine the volume of lumber, by grade, that is required to fill a specified cutting bill. Multiplying these volume estimates by the cost of lumber gives us the grade of lumber with the lowest raw material cost.

It is common practice in the furniture industry to limit the length of cuttings produced from No. 2 Common lumber to 40 inches, and the FPL yield data reflect this practice. Their predictions of dimension stock yields for No. 2 Common are, therefore, limited to cuttings between 10 and 40 inches long. We extended their simulation model by increasing the minimum cutting length from 10 to 18 inches and the maximum length

from 40 to 60 inches. Both of these changes would normally be expected to reduce the overall yield.

## Computer Simulation

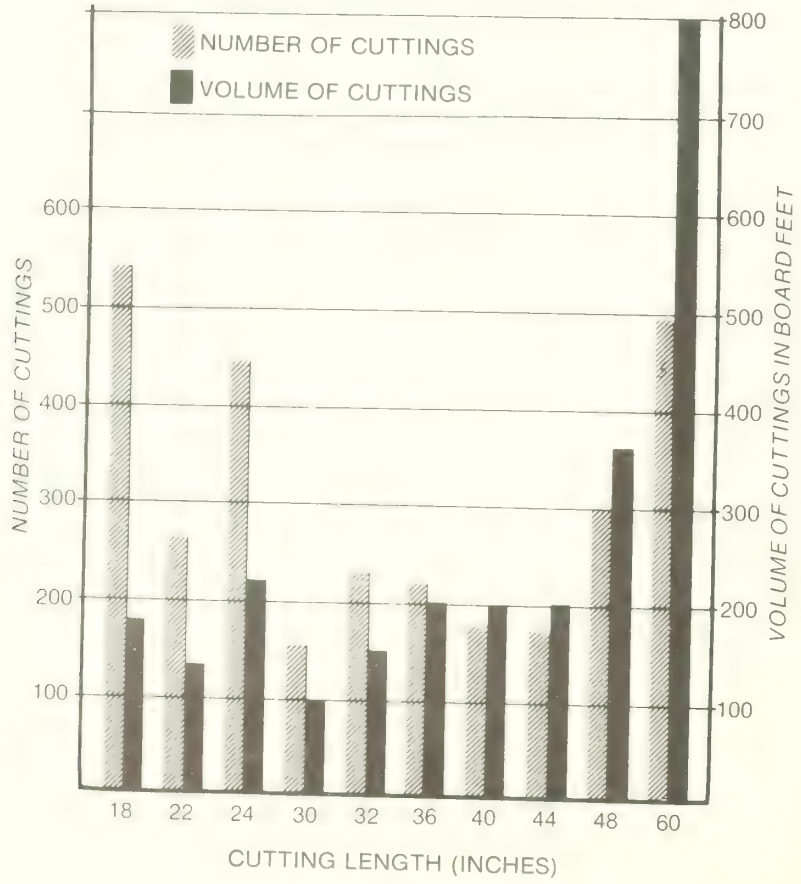
Our computer program simulates the cutting up of a board into dimension parts of specified sizes, maximizing the total area of the cuttings obtained from the board. The program obtains its cuttings in a manner compatible with conventional rough mill cut-up procedures. For example, all cuts made must run the full width or length of the board or section of board being analyzed. The initial cut on the board may be either a rip or a crosscut. If the first cut is a rip, then the rip line must run the entire length of the board. Likewise, if the first cut is a crosscut, it must extend across the entire width of the board. After the initial cuts are made, subsequent cuts need only extend across the length or width of the sections of the board produced by the original cuts.

The desired cutting lengths and widths must be specified. The computer program accommodates up to 10 widths and 10 lengths and will allow any combination of them; thus a cutting bill of 100 different sizes is possible. The program orders the cuttings on the basis of area, the cutting having the largest area being ordered first. In cases where the cutting area is the same for two or more cuttings, the longer length is given priority. We used the following sizes:

Widths: 1½, 2, 2½, 3, 3½, 4, 4½, 5, 5½, and 6 inches.

Lengths: 18, 22, 24, 30, 32, 36, 40, 44, 48, and 60 inches.

Figure 1.—Yield, by number and volume, of C1F dimension parts from No. 2 Common oak lumber.



In addition to the specification of cutting sizes, the program requires input data on the location of all defects within each board. To provide these data, we collected a sample of 637 No. 2 Common 4/4 red and white oak boards and recorded the locations of all defects on them. Each defect was coded to indicate the type of defect and whether it occurred on the grade side or the back side of the board. Twenty-three defect types were recognized and recorded.

Our 637-board sample contained a total volume of 4,625 board feet in boards ranging from 4 to 16 feet in length and from 3 to over 16 inches in width. The sample was selected from four mills (three in West Virginia and one in Virginia). The lumber was kiln dried to an average moisture content of 7 percent.

## RESULTS

While No. 2 Common lumber is commonly used to produce short cuttings, our results show that there is a higher potential for larger length cuttings than is normally thought. For example (fig. 1), the volume recovered in 60-inch cuttings was four times that of the 18-inch cuttings (806 versus 186 board feet). In fact, each of the cutting length classes 36 inches long and longer contained more volume than the 18-inch class.

One-third (1,554 board feet) of the original board volume was recoverable in cuttings 40 inches and longer (table 1). The 60-inch cuttings accounted for more volume, 17.4 percent, than any of the other cutting lengths. It is important to note that the high yields in these longer lengths were not obtained at the expense of overall yield from the lumber. Of the total board volume in the sample, over half (2,544 board feet) was recoverable in C1F cuttings.

In addition to the volume of cuttings obtained, the distribution of the cuttings by length and width was recorded (table 2). All 100 possible cutting sizes were represented in the yield. Only 15 percent of the cuttings recovered would be classified as small cuttings, that is, cuttings less than 24 inches long and also less than 3 inches wide. Eighty-five percent of the total number of cuttings would therefore be classified as large. The 60-inch

*Table 1.—Board foot volume and percent yield by cutting length of C1F dimension parts produced from a representative sample of No. 2 Common oak lumber*

| Cutting length (inches) | Yield by length class | | Cumulative Yield (top to bottom) | |
|---|---|---|---|---|
| | Board foot volume | Percent of total board volume[a] | Board foot volume | Percent of total board volume |
| 60 | 806 | 17.4 | 806 | 17.4 |
| 48 | 357 | 7.7 | 1,163 | 25.1 |
| 44 | 199 | 4.3 | 1,362 | 29.4 |
| 40 | 192 | 4.2 | 1,554 | 33.6 |
| 36 | 193 | 4.2 | 1,747 | 37.8 |
| 32 | 160 | 3.5 | 1,907 | 41.3 |
| 30 | 105 | 2.3 | 2,012 | 43.6 |
| 24 | 219 | 4.7 | 2,231 | 48.3 |
| 22 | 127 | 2.7 | 2,358 | 51.0 |
| 18 | 186 | 4.0 | 2,544 | 55.0 |
| Total | 2,544 | 55.0 | | |

[a]Base: 4,625 board feet of lumber input.

Table 2.—*Length and width distribution of C1F dimension parts produced from a representative sample of No. 2 Common oak lumber*

| Cutting length | Number of cuttings by width of cutting (inches) | | | | | | | | | | Total | Percent of total cuttings | Cumulative percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1½ | 2 | 2½ | 3 | 3½ | 4 | 4½ | 5 | 5½ | 6 | | | |
| 60 | 22 | 33 | 43 | 83 | 54 | 69 | 50 | 53 | 23 | 66 | 496 | 16.7 | 16.7 |
| 48 | 36 | 35 | 19 | 37 | 31 | 34 | 27 | 17 | 21 | 37 | 294 | 9.9 | 26.6 |
| 44 | 22 | 14 | 13 | 22 | 21 | 19 | 16 | 20 | 19 | 11 | 177 | 5.9 | 32.5 |
| 40 | 19 | 15 | 18 | 15 | 14 | 24 | 21 | 12 | 16 | 26 | 180 | 6.0 | 38.5 |
| 36 | 35 | 18 | 20 | 21 | 21 | 23 | 22 | 14 | 17 | 24 | 215 | 7.2 | 45.7 |
| 32 | 50 | 27 | 24 | 23 | 24 | 27 | 11 | 10 | 5 | 24 | 225 | 7.6 | 53.3 |
| 30 | 23 | 17 | 20 | 18 | 16 | 16 | 10 | 9 | 8 | 13 | 150 | 5.0 | 58.3 |
| 24 | 107 | 80 | 49 | 47 | 38 | 29 | 19 | 13 | 21 | 36 | 439 | 14.8 | 73.1 |
| 22 | 60 | 34 | 34 | 31 | 17 | 18 | 13 | 21 | 13 | 21 | 262 | 8.8 | 81.9 |
| 18 | 163 | 95 | 68 | 62 | 38 | 23 | 26 | 21 | 14 | 29 | 539 | 18.1 | 100.0 |
| Total | 537 | 368 | 308 | 359 | 274 | 282 | 215 | 190 | 157 | 287 | 2,977 | 100.0 | — |
| Percent | 18.0 | 12.4 | 10.3 | 12.1 | 9.2 | 9.5 | 7.2 | 6.4 | 5.3 | 9.6 | — | — | — |
| Cumulative percent | 100.0 | 82.0 | 69.6 | 59.3 | 47.2 | 38.0 | 28.5 | 21.3 | 14.9 | 9.6 | — | — | — |

[a]Base: 2,977 cuttings

cuttings alone accounted for 16.7 percent of the total number of cuttings produced.

## DISCUSSION

These results suggest that the yield of long cuttings is sufficient to make No. 2 Common lumber the most economical choice for a wide range of cutting lengths. Comparing the raw material costs to produce 1,000 board feet of 1½ by 40 inch C1F parts from FAS, No. 1 Common, and No. 2 Common oak lumber, we find:

| *Grade* | *Yield* % | *Lumber required to produce 1,000 board feet of parts bf* | *Lumber cost/Mbf* | *Cost of 1,000 board feet of parts* |
|---|---|---|---|---|
| FAS | 61[a] | 1,639 | $245 | $401 |
| 1C | 47[a] | 2,128 | 135 | 287 |
| 2C | 34[b] | 2,941 | 85 | 250 |

[a]Percent yield taken from charts in reference *1*.
[b]Percent yield taken from table 1.

Thus on the basis of the cost of raw material only, No. 2 Common lumber is clearly the most economical choice. However, a complete economic analysis must also take into consideration the manufacturing system and the relative costs of processing different grades of lumber.

The present method of converting lumber to dimension parts is to process a board through a series of crosscuts and rips to conform to a particular cutting bill. In other words, once a board is brought into the system it is processed through to completion. The computer simulation program we used functions in the same way, but the speed, accuracy, and analytical capabilities of the computer are infinitely greater than those of the saw operator. The yields were high for No. 2 Common because we used 100 different cutting sizes. However, we cannot expect the yields in a production plant to equal them; a crosscut operator cannot carry 100 different cutting sizes in his head and at the same time keep his rate of production and yield at a satisfactory level.

No manufacturing system can change the yield potential of a board, but one can affect the probability of attaining that potential. To realize the maximum potential of long cuttings from No. 2 Common lumber, changes must be made in the present manufacturing process. The length and width distribution of the cuttings obtained from our sample of No. 2 Common lumber justifies additional research to develop alternate methods of processing lumber into dimension parts. Accordingly, we have started to investigate the effect that rough mill cut-up practices have on the recovery of long length cuttings from low grades of lumber. We have designed a rough mill computer simulation model to develop a set of decision rules on how best to process low-grade lumber into dimension parts.

Although the quality of the lumber determines what cuttings you can get, the saw operator determines what you will get. Therefore, whatever decision rules are developed must be easily translatable into instructions that can be put into practice by the saw operator.

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# A SPRAY TOWER For the Application of MICROBIAL AERIAL SPRAYS

by Harry B. Hubbard, Jr.
Franklin B. Lewis

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WARREN T. DOOLITTLE, DIRECTOR

## The Authors

HARRY B. HUBBARD, JR., Biological Laboratory Technician, joined the staff of the Northeastern Forest Experiment Station in 1957. He has taken courses in Biology at Quinnipiac College and received on the job training in needed fields. His main effort is in the field of forest-insect pathogen studies at the Forest Insect and Disease Laboratory at Hamden, Conn.

FRANKLIN B. LEWIS received his Bachelor of Science degree in entomology from Union College, Schenectady, New York, 1948. From 1949 to 1953 he was a laboratory instructor at the University of Connecticut, then he worked as a research assistant at the university for a year. He earned both his Master of Science and Ph.D. degrees in entomology from the university in 1950 and 1955 respectively. Dr. Lewis joined the staff of the Northeastern Forest Experiment Station in 1955 and has concentrated mostly on spruce budworm parasite and forest-insect pathogen studies at the Station's Forest Insect and Disease Laboratory at Hamden, Conn.

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# A SPRAY TOWER For the Application of MICROBIAL AERIAL SPRAYS


## Abstract

An experimental spray tower for the application of aerial sprays is described. The construction, operation, and preliminary calibration are detailed.


## INTRODUCTION

THE TRANSLATION of laboratory-acquired bioassay data into field dosage specifications has been a recurrent problem in insecticide research and development programs.

This problem is further complicated by the fact that microbial insecticides (with which we are experimenting) are: (1) usually formulated as water suspensions, thus creating an evaporation problem in the field that is not encountered in laboratory testing; (2) effective only when eaten, thus requiring thorough coverage of the food plant—a major problem in the forest, but of negligible consequence in laboratory testing; (3) presented to the test larvae in the laboratory by methods that bear little resemblance to the form of presentation under field conditions—macrofeeding or injection, incorporation of known concentrations into artificial diet, feeding of foliage dipped into known concentrations, or carefully controlled application by hand sprayer on individual leaves or small bouquets.

Laboratory data acquired by any of the above techniques are often extrapolated to field dosages. Microorganisms that were very promising in laboratory tests performed poorly or unacceptably in the field.

Extrapolation of laboratory data to field dosage selection can be improved by creating an artificial forest (placing potted trees in open fields) and spraying from aircraft, or by simulating aerial application.

We have constructed and tested a spray tower that simulates aerial spray deposit, distribution, penetration, and volume per acre.

It was developed from a rain simulator developed by Dr. Bohdan Maksymiuk *(1959)*. Four trees, 1 to 5 feet in height can be treated simultaneously.

Figure 1.—Outside view of tower. Doors are shut while tower is in operation.

## TOWER SPECIFICATIONS

### Construction

The tower is constructed of framing-grade lumber and sheet plywood covering (fig. 1). An enclosed operator's platform on the side houses the controls. A plexiglass observation window permits the operator to view the spray delivery and to adjust the controls as necessary. Samples are introduced to and removed from the chamber by double doors. The inside of the chamber is 8x8x11 feet.

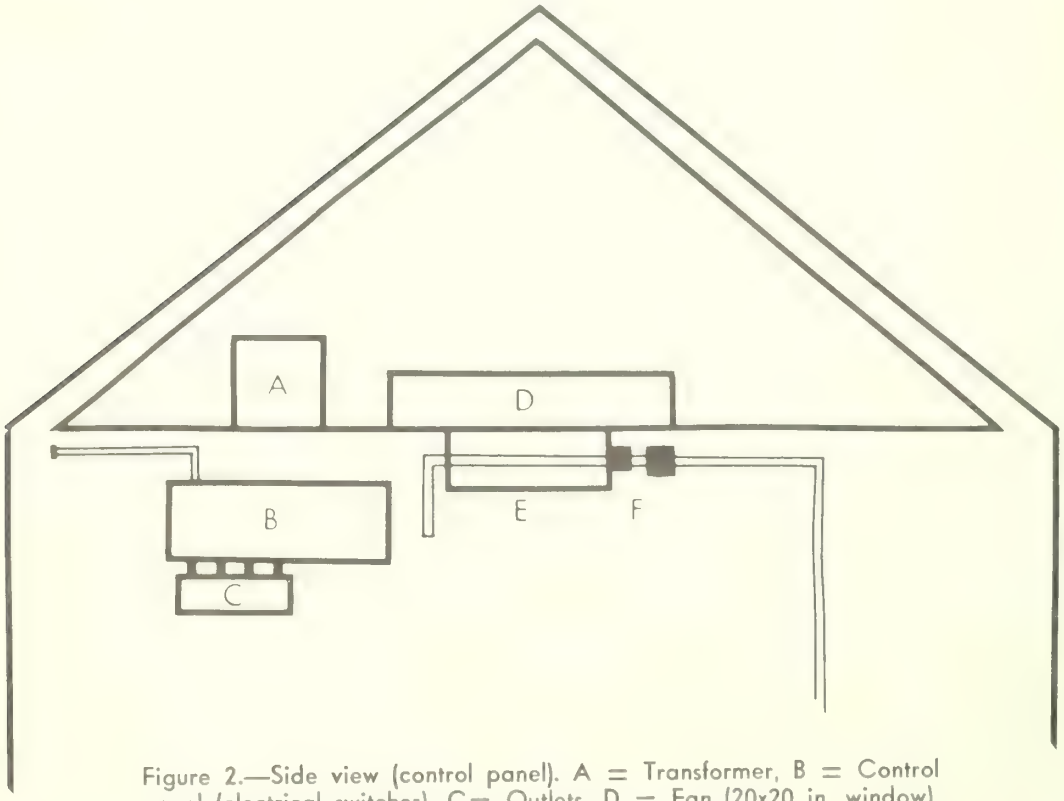



Figure 2.—Side view (control panel). A = Transformer, B = Control panel (electrical switches), C= Outlets, D = Fan (20x20 in. window), E = Observation window, and F = Control valves (air).

## Power Controls and Equipment Outside Chamber

A control panel (figure 2) is built into the operator's platform near the plexiglass window. Air for spray delivery is piped through copper tubing to the control center on the tower and controlled by a pressure regulator with a gage and a shutoff valve within easy reach of the operator.

## Equipment within the Chamber

An explosion proof lighting fixture is mounted at the top back of the chamber so that the spray drops can be seen.

A 20-inch window exhaust fan controlled by a rheostat is mounted in the top center of the chamber and baffled to produce a swirling airflow into which the spray is introduced.

The main equipment is a double turntable device for exposing test specimens equally to the spray (fig. 3 and 4).

It consists of a large turntable (72 inches in diameter) on which are mounted four smaller turntables (30 inches). The turntables were made of ¾-inch plywood covered with formica.

The large turntable is supported at four cardinal points by pillow blocks topped with rubber casters. A sheet-steel track on the underside of the turntable reduces friction between the turntable and the casters. These supports keep the turntable balanced when the load on it is unevenly distributed.

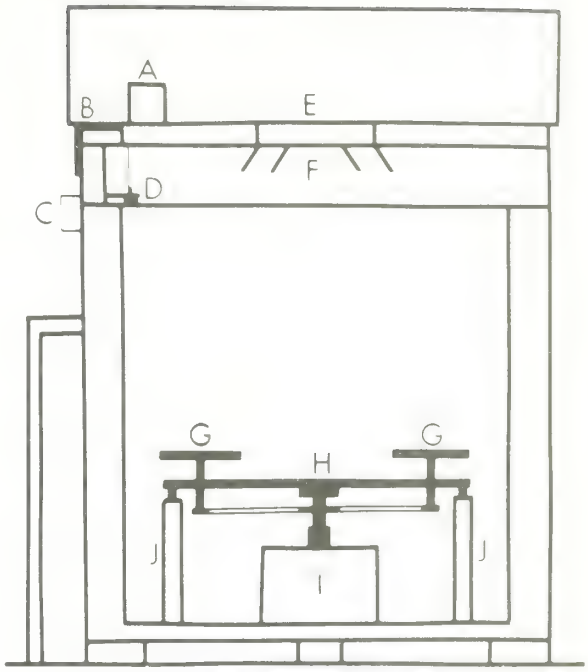
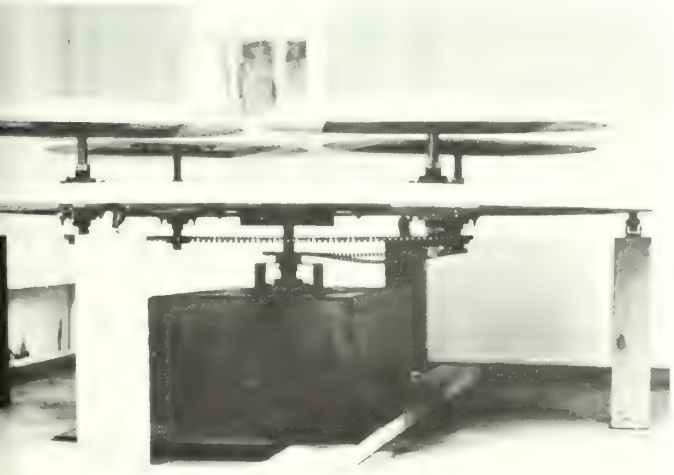



Figure 4. — Front view of tower. A = Transformer, B = Observation window, C = Control panel, D = Nozzle, E = Fan, F = Baffles, G = Small turntables, H = Large turntable, I = Gearbox drive, and J = Pillow blocks.

Figure 3.—Turntable, showing gear box, chain drive, and casters for support of turntable.



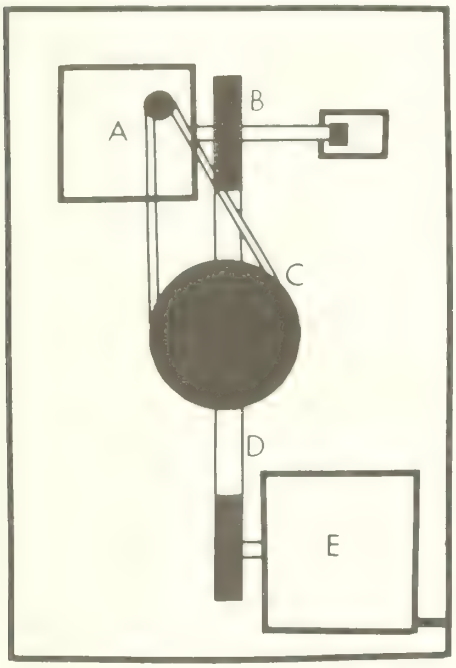
The four small turntables are mounted on the large turntable at 90° intervals. Their shafts pass through bearings on the large turntable. Sprockets welded on the shafts transmit power through bicycle-type chain from the big turntable shaft to the four small turntables.

The gear ratio is fixed so that the small turntables make three revolutions for each revolution of the large turntable. The chains have idler sprockets to keep tension constant at all times.

## Main Power Gearbox

The motor, pulleys, and gears were mounted in a sheet steel box. A variable speed pulley on the gearbox allows the rota-

Figure 5.—Power system. A = right angle reducing gearbox, B = Variable speed adjustable pulley, C = Double v-belt and pulley drive to turntables, D = V-belt drive from motor to gearbox, and E = Motor.




tion of the large turntable to be adjusted from 0 to 3 r.p.m. (fig. 5).

From the output shaft of the gearbox, the power is transmitted to the main shaft by double pulleys and v-belts. Double idler pulleys keep the proper tension on the belts. This belt drive allows for slippage in starting to minimize damage to other parts. A list of parts is given in Appendix A.

### Spray Delivery

The spray nozzle is mounted by the operator's window and pointed into the airflow from the fan. It produces a round spray pattern.

Because the air passing through this nozzle produces suction at the liquid entrance port, precise quantities as small as 1 milliliter of experimental spray materials can be introduced into the spray chamber. This system can deliver from 0.2 to 10 gallons per acre.

## TOWER OPERATION

1. The plant material to be sprayed is placed on the small turntables. Usually, potted trees 1 to 4 feet high are used. Trees of about the same size are placed 180 degrees apart to help balance the turntables.
2. The air compressor is turned on, and air pressure is adjusted between 40 and 60 p.s.i. to give the desired droplet size range.
3. The speed of the large turntable is adjusted to give at least one full rotation during delivery of the selected volume of spray.
4. The operator takes his position in the operator's platform. The plastic line with cannula attached to the liquid entry port of the spray nozzle is placed in the container holding the spray to be delivered.
5. The turntable is switched on, and the air valve is opened. The spray is then delivered into the spray chamber.
6. When all the spray has been delivered, the air valve is closed. The plant material remains in the closed tower for an additional 3 minutes.

The tower is best operated with one man to place and remove the plant material while the operator remains in the platform to oversee the entire operation and to flush the system between spray changes. The spray system is disinfected by flushing with 0.5 percent sodium hypochlorite, and the inside of the tower is washed with the same solution.

The total cost of construction of the tower was about $750.

## TOWER CALIBRATION

General distribution of the spray from the tower was measured by spraying four 3-foot trees with a water-soluble fluorescent dye (Fire Orange A-14). The trees were examined under ultraviolet light to determine the uniformity of the deposit. No attempt was made to size the droplets by this technique.

Droplet size distribution was evaluated, using the technique described by Fisher and

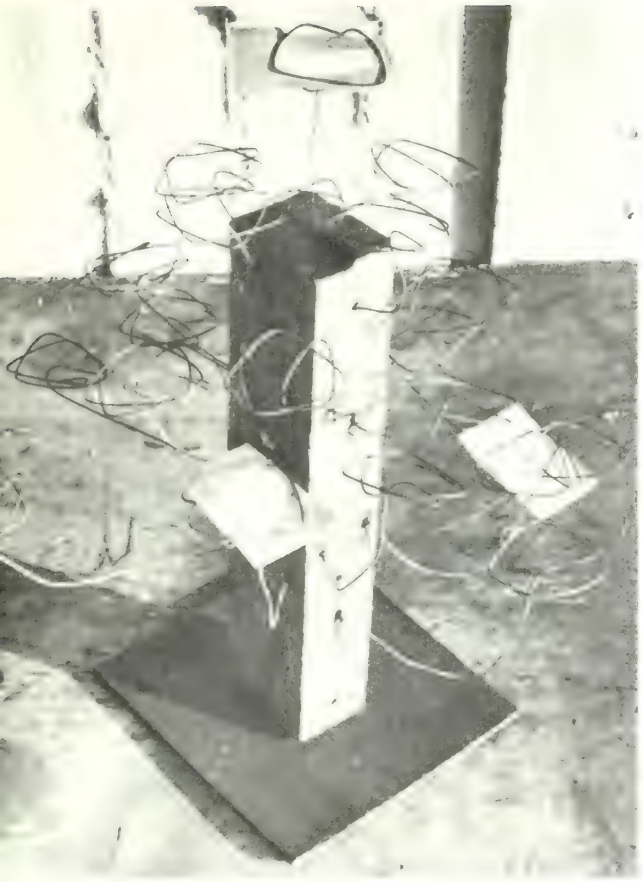


Figure 6.—Artificial tree for spray calibration.

Dougan *(1970)*. This system uses a very viscous butylene polymer[1] to trap the spray droplets and an image-splitting eyepiece to measure droplet size.

Polymer-coated slides were placed into wire holders *(Maksymiuk 1959)* and were introduced into a chamber. They were sprayed with 50 milliliters of a dye suspension which was left to settle for 3 minutes. The slides were removed; and polymer-coated cover slips were placed on top of them, trapping the spray droplets between the two layers of polymer.

[1]Indopol polybutene #1900, Amoco Chemical Corporation. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U. S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

A stand for the wire holders was constructed of a flat 12x12-inch plywood base with a 4x4-inch piece of lumber nailed in the center at 90 degrees to form an upright. Holes were drilled in the 4x4-inch board at a 45-degree angle. Any number of wire card holders can be placed on the stand at any one time. When all the wire holders are placed on the stand, it takes on the shape of a tree (fig. 6).

For the tower calibration, three wire holders were placed on the artificial tree at 10, 20, and 36 inches from the small turntable.

The droplets were sized in five categories (20$\mu$ or less, 21-40$\mu$, 41-80$\mu$, 81-160$\mu$, and greater than 160$\mu$). These data are presented in Appendix B. The cumulative number of drops and cumulative drop volume were plotted on log-log paper, and number median diameter (NMD) and mass median diameter (MMD) were read. MMD's produced in the tower ranged from 100 to 103 microns.

## SUMMARY

As evidenced by the data on droplet volume and distribution (Appendix B), the spray tower produces very uniform spray patterns. The mass median diameters (MMD) at the three levels of sampling were very close and fell within the size range desired (80-125$\mu$).

The results of the construction and operation of the tower have met the planned objectives.

We have plans to further test this unit and make modifications as needed.

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# APPENDIX A

| *List of Parts* | *Quantity* |
|---|---|
| 1-inch bore sprockets | 4 |
| 1-inch bore sprocket | 1 |
| 1¼-inch bore sprocket | 1 |
| 1-inch bore pillow blocks | 4 |
| 1¼-inch bore pillow block | 1 |
| 1-inch shaft collars | 4 |
| 1¼-inch shaft collar | 1 |
| VS 113-300: 1 gear reductor mounting assembly | 1 |
| Eaton, Yale & Towne #6400M ½-inch bore manually controlled pulley (with control v-belt) | 1 |
| ⅝-inch bore pulley (v-belt) | 1 |
| 1¼-inch bore double pulley (v-belt) | 1 |
| ⅝-inch bore double pulley (v-belt) | 1 |
| Roller chain | 1 |
| General Electric ¼ hp a.c. 1750 r.p.m. 115 v. 4.4 amp. motor | 1 |
| Morse Serial D8690131 Ratio 300 1/10 hp. 1750 r.p.m. gearbox | 1 |
| Spray Systems ¼ JP pneumatic atomizing nozzle, setup #11, fluid nozzle #2050, air nozzle #67147 | 1 |

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# APPENDIX B

Table 1. — *Droplet number and volume distribution, series I*

| Size class | Height of tree sample | Drops | Total volume | Volume as percent | Cumulative volume as percent | Number as percent | Cumulative number as percent | |
|---|---|---|---|---|---|---|---|---|
| *Microns* | *In.* | *No.* | *Cubic microns* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | |
| 20 | 36 | 230 | 963,447.0 | 0.011 | 0.011 | 0.52 | 0.52 | |
| 40 | " | 123 | 4,122,357.3 | .048 | .059 | .27 | .79 | MMD |
| 80 | " | 62 | 16,623,247.8 | .193 | .252 | .14 | .93 | 101.0 |
| 160 | " | 27 | 57,913,320.6 | .673 | .925 | .06 | .99 | |
| >160 | " | 3 | 6,434,813.4 | .075 | 1.00 | .01 | 1.00 | |
| Total | — | 445 | 86,057,186.1 | | | | | |
| 20 | 20 | 207 | 867,102.3 | .011 | .011 | .50 | .50 | |
| 40 | " | 99 | 3,317,994.9 | .043 | .054 | .24 | .74 | MMD |
| 80 | " | 82 | 21,985,585.8 | .283 | .337 | .20 | .94 | 101.2 |
| 160 | " | 22 | 47,188,631.6 | .608 | .945 | .05 | .99 | |
| >160 | " | 2 | 4,289,875.6 | .055 | 1.00 | .01 | 1.00 | |
| Total | — | 412 | 77,649,189.7 | | | | | |
| 20 | 10 | 221 | 925,746.9 | .010 | 0.10 | .54 | .54 | |
| 40 | " | 92 | 3,083,389.2 | .035 | .045 | .22 | .76 | MMD |
| 80 | " | 66 | 17,695,715.4 | .201 | .246 | .16 | .92 | 103.1 |
| 160 | " | 29 | 62,203,196.2 | .705 | .951 | .07 | .99 | |
| >160 | " | 2 | 4,289,875.6 | .049 | 1.00 | .01 | 1.00 | |
| Total | — | 410 | 88,197,923.3 | | | | | |

Table 2. — *Droplet number and volume distribution, series II*

| Size class | Height of tree sample | Drops | Total volume | Volume as percent | Cumulative volume as percent | Number as percent | Cumulative number as percent | |
|---|---|---|---|---|---|---|---|---|
| *Microns* | *In.* | *No.* | *Cubic microns* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | |
| 20 | 36 | 724 | 3,032,763.6 | 0.046 | 0.046 | 0.80 | 0.80 | |
| 40 | " | 106 | 3,552,600.6 | .054 | .100 | .12 | .92 | MMD |
| 80 | " | 51 | 13,673,961.9 | .209 | .309 | .05 | .97 | 100.3 |
| 160 | " | 19 | 40,753,818.2 | .624 | .933 | .02 | .99 | |
| >160 | " | 2 | 4,289,875.6 | .066 | .999 | .01 | 1.00 | |
| Total | — | 902 | 65,303,019.9 | | | | | |
| 20 | 20 | 600 | 2,513,340.0 | .034 | .034 | .77 | .77 | |
| 40 | " | 98 | 3,284,479.8 | .045 | .079 | .12 | .89 | MMD |
| 80 | " | 60 | 16,087,014.0 | .219 | .298 | .08 | .97 | 100.0 |
| 160 | " | 19 | 40,753,818.2 | .556 | .854 | .02 | .99 | |
| >160 | " | 5 | 10,724,689.0 | .146 | 1.00 | .01 | 1.00 | |
| Total | — | 782 | 73,363,341.0 | | | | | |
| 20 | 10 | 511 | 2,140,527.9 | .058 | .058 | .78 | .78 | |
| 40 | " | 98 | 3,284,479.8 | .089 | .147 | .15 | .93 | MMD |
| 80 | " | 37 | 9,920,325.3 | .270 | .417 | .06 | .99 | 101.4 |
| 160 | " | 8 | 17,159,502.4 | .466 | .883 | .01 | 1.00 | |
| >160 | " | 2 | 4,289,875.6 | .116 | .999 | .00 | 1.00 | |
| Total | — | 656 | 36,794,711.0 | | | | | |

Table 3. — *Droplet number and volume distribution, series III*

| Size class | Height of tree sample | Drops | Total volume | Volume as percent | Cumulative volume as percent | Number as percent | Cumulative number as percent | |
|---|---|---|---|---|---|---|---|---|
| *Microns* | *In.* | *No.* | *Cubic microns* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | |
| 20 | 36 | 728 | 3,049,519.2 | 0.023 | 0.023 | 0.65 | 0.65 | |
| 40 | " | 203 | 6,803,565.3 | .052 | .075 | .18 | .83 | |
| 80 | " | 163 | 43,703,054.7 | .334 | .409 | .14 | .97 | MMD |
| 160 | " | 36 | 77,217,760.8 | .590 | 99.9 | .03 | 1.00 | 100.6 |
| >160 | " | 0 | 0 | .0 | .999 | 0 | 0 | |
| Total | — | 1,130 | 130,773,900.0 | | | | | |
| 20 | 20 | 466 | 1,952,027.4 | .018 | .018 | .58 | .58 | |
| 40 | " | 200 | 6,703,020.0 | .061 | .079 | .25 | .83 | |
| 80 | " | 107 | 28,688,508.3 | .260 | .339 | .13 | .96 | MMD |
| 160 | " | 34 | 72,927,885.2 | .661 | 1.00 | .04 | 1.00 | 100.5 |
| >160 | " | 0 | 0 | 0 | 1.00 | 0 | 0 | |
| Total | — | 807 | 110,271,440.9 | | | | | |
| 20 | 10 | 395 | 1,654,615.5 | .016 | .016 | .55 | .55 | |
| 40 | " | 183 | 6,133,263.3 | .058 | .074 | .25 | .80 | |
| 80 | " | 115 | 30,833,443.5 | .286 | .360 | .16 | .96 | MMD |
| 160 | " | 29 | 62,203,196.2 | .592 | .952 | .04 | 1.00 | 102.5 |
| >160 | " | 2 | 4,289,875.6 | .041 | 99.3 | 0 | 0 | |
| Total | — | 724 | 105,114,394.1 | | | | | |

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# The Rate of Value Increase for SUGAR MAPLE

by Joseph J. Mendel
Ted J. Grisez
G. R. Trimble, Jr.

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

JOSEPH J. MENDEL, principal economist, received his bachelor of science degree in forestry from the University of Michigan in 1941, and his master's degree and Ph.D. in agricultural economics from Ohio State University in 1963 and 1965 respectively. He also studied at the University of Wisconsin and the University of Cincinnati. He joined the Northeastern Forest Experiment Station in 1946, working first on forest surveys, and in 1952 transferred to the Washington Office of the Forest Service as a photo-interpretation specialist in the Division of Forest Economics. After 6 years in Washington he accepted a position as research forester with the Central States Forest Experiment Station at Columbus, Ohio, and in 1966 transferred to the Northeastern Station, where he is now serving as a specialist in forest economics at the Station's research unit in Columbus, Ohio.

TED J. GRISEZ received a bachelor's degree in forestry from the University of Michigan in 1943. He also attended Ohio State University from 1939 to 1941. After military service in World War II, he joined the Northeastern Forest Experiment Station in 1946. For 6 years he was assigned to the Station's forest-survey unit, and for the past 19 years to the Station's timber-management-research programs, first in Maine and later in Pennsylvania. He is now a silviculturist for the research unit on silviculture of Allegheny hardwoods at Warren, Pennsylvania.

G. R. TRIMBLE, JR., is a timber-management project leader for the Northeastern Forest Experiment Station at its Timber and Watershed Laboratory at Parsons, West Virginia. He received his forestry training at the University of Maine. He worked for a number of years in watershed-management research both in West Virginia and New Hampshire and has worked on forest-management problems throughout most of the Northeastern States.

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# The Rate of Value Increase for SUGAR MAPLE


## Abstract

Presents financial-maturity information for sugar maple, based on tree growth and tree-quality data collected in Pennsylvania and West Virginia. Detailed rates of value increase and dollar value increase to be expected for a 10-year period are exhibited. Marking guides in the form of financial-maturity diameters are developed. The effects on financial maturity of operating at different levels of conversion costs and changing costs and prices are analyzed.


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## BACKGROUND

THIS IS THE FOURTH in a series of reports about the rate of value increase of the more important hardwood timber species in the Northeast.

These reports have illustrated the relative importance of diameter growth, the increase in merchantable height, and the improvement in quality for determining present and future tree value. They have established the rates at which trees can be expected to increase in value over a 10-year period and have identified the relative sizes at which trees become financially mature. However, most important of all, these reports have characterized the joint relationship that must exist between silviculture and economics for determining the financial maturity of trees and stands for timber production.

Throughout the production of these reports, there has been a progressive development toward a higher order of timber-stand evaluation.

The first report—on the oaks—was concerned primarily with the development of methodology and the presentation of the expected rates of value increase and financial maturity diameters.

The second report—on yellow-poplar and beech—illustrated the differences in results between high- and low-value species, and a computer program was developed to produce the multitude of calculations necessary for the valuation of a single species.

The third report—on black cherry, white ash, and red maple—utilized the methodology to illustrate the application of financial maturity to the even-aged management of intolerant species. Detailed tables of the dollar-value increase were presented.

This fourth report, in addition to presenting the basic tables of expected rates of value increase and financial maturity diameters and detailed tables on the *rate* and *dollar* value increase for sugar maple (*Acer saccharum*), will show how different levels of conversion costs—and the dynamic and realistic market situation of changing lumber prices and conversion costs—affect the determination of financial maturity.

## THE RATE OF VALUE INCREASE

The value of a timber tree is influenced by its diameter, merchantable height, and quality. Over a period of time, we can expect improvements in these elements of a tree, which will increase its value. Our objective is to determine the rate at which this value increase takes place, so that valid comparisons with other financial investments can be made.

The rate of value increase is calculated by the use of the compound-interest formula

$$(1 + r)^n = \frac{V_n}{V_o}$$

in which

r is the rate of interest (value increase).

n is the time period (10 years).

$V_n$ is the future value of the tree at the end of the 10-year period.

$V_o$ is the present value of the tree.

It is evident in the formula that, to calculate the rate of value increase, we must first determine the present and future value of the tree. The procedure used in developing the present and future values and computing the rates of value increase are presented in detail in two earlier research papers (*Trimble and Mendel 1969; Mendel and Trimble 1969*), and readers interested in the details of this procedure should refer to one of these publications.

We will briefly review the procedure, primarily for purposes of documentation of source material and data used. Figure 1 presents a schematic version of the basic procedure when there is no anticipated change over the 10-year period in the basic price of 4/4 No. 1 Common lumber or in the cost of converting the tree into lumber.

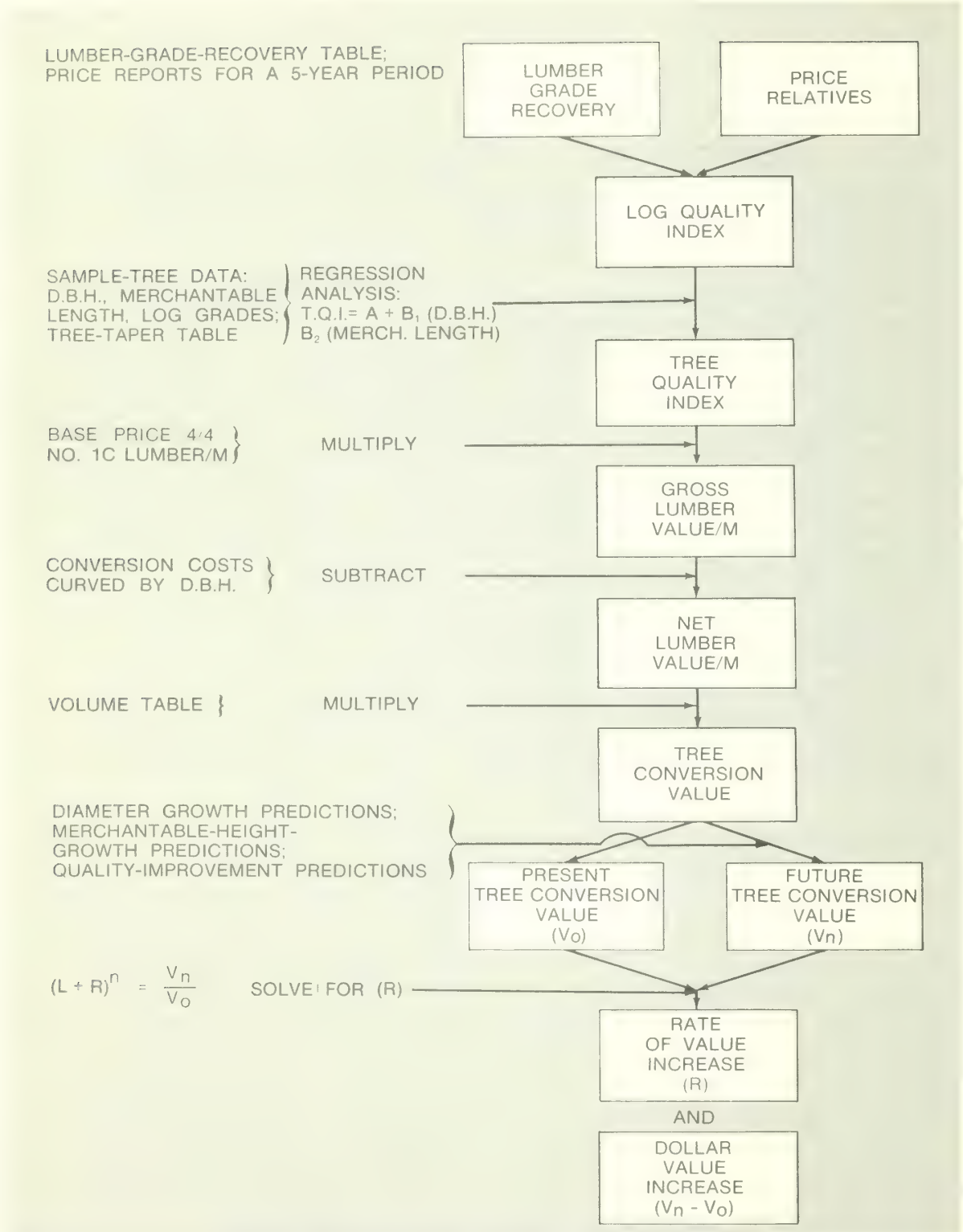



Figure 1.—Calculation of the rate of value increase.

Lumber-grade recovery data for sugar maple by log grade and size-grade combinations were obtained from the USDA Forest Products Laboratory (*Vaughan and others 1966*). Lumber prices used were those reported in the Hardwood Market Report (*Lemsky 1962-66 and 1968*). Prices for the 5-year period 1962-66 were used in developing the price relatives for calculation of the log-quality index (table 1). The 1968 report was used to determine the base price of $185 per M (1,000) board feet for 4/4 No. 1 Common sugar maple. This was the base period for value determinations.

Sample-tree data for determining the log-grade relationship between the butt log and the upper merchantable logs for various diameters were obtained from 144 sugar maple trees selected at random in the Appalachian Region and 54 sugar maple trees similarly selected in the Allegheny Region.

In this study, three levels of conversion costs were recognized: $60, $70, and $80 per M board feet for a 16-inch d.b.h. tree (table 2). The costs were curved by tree d.b.h.'s, and the results were applied by tree d.b.h. classes to determine the net value per M board feet.

Tree-conversion value was calculated by multiplying the net value per M board feet by the volume in the tree. The ¼-inch International volume table was used to determine the volumes. Present values for trees can be read directly from the tree-conversion value tables resulting from these calculations.

To determine future value of the tree we must establish the changes that can occur over the 10-year period in diameter growth, merchantable height, and quality.

A study of 385 sugar maple trees from 12 to 30 inches d.b.h. was made to develop equations for estimating the 10-year diameter growth for each vigor class in northern hardwood stands (table 8, in appendix). It was assumed that vigor class would remain the same during the next 10 years.

To guide the projection of log-height increase, we made the following assumptions:

1. A tree growing 2.0 inches d.b.h and more during the 10-year period could potentially grow a full 16-foot log in merchantable height. Trees growing less than 2.0 inches d.b.h. in 10 years were limited to a ½-log increase in merchantable height.
2. Since log-height increases are related to the diameter of the tree, the following limitations were made for computation purposes.

Table 1.—Lumber price relatives for sugar maple

| Lumber grade | Price relative |
|---|---|
| FAS | $1.57 |
| SEL | 1.51 |
| No. 1C | 1.00 |
| No. 2C | .45 |
| No. 3A | .38 |
| No. 3B | .27 |

[1] Based on 1962-66 Hardwood Market Report prices for Appalachian hardwoods, f.o.b. mills in the area of Johnson City, Tennessee. 4/4 plain-sawed No. 1 Common grade was used as reference.

Table 2.—Conversion costs for hardwood trees

| Tree d.b.h. (inches) | Cost per M board feet |
|---|---|
| $60.00 LEVEL | |
| 12 | $68.80 |
| 14 | 64.40 |
| 16 | 60.00 |
| 18 | 55.60 |
| 20 | 51.20 |
| 22 | 46.80 |
| 24 | 43.40 |
| 26 | 42.25 |
| 28 | 41.85 |
| 30 | 41.75 |
| $70.00 LEVEL | |
| 12 | 78.85 |
| 14 | 74.50 |
| 16 | 70.00 |
| 18 | 65.70 |
| 20 | 61.35 |
| 22 | 57.00 |
| 24 | 53.50 |
| 26 | 52.25 |
| 28 | 51.95 |
| 30 | 51.85 |
| $80.00 LEVEL | |
| 12 | 88.80 |
| 14 | 84.40 |
| 16 | 80.00 |
| 18 | 75.55 |
| 20 | 71.15 |
| 22 | 66.80 |
| 24 | 63.35 |
| 26 | 62.10 |
| 28 | 61.75 |
| 30 | 61.65 |

| *Present d.b.h. (inches)* | *Tree height classes that will not increase in height in next 10 years* |
|---|---|
| 18 | 1-log trees |
| 20 | 1- and 1½-log trees |
| 22 | 1-, 1½- and 2-log trees |
| 24 | 1-, 1½-, 2-, and 2½-log trees |
| 26 | No increase in log height for any trees 26 inches d.b.h. or over |

3. Maximum log height used in the computation was 64 feet.

The assumptions about quality-improvement predictions were:

1. The maximum butt-log grade improvement would be one grade class.
2. In trees larger than 15 inches d.b.h., no improvement was computed for trees with butt logs of construction or local-use class.
3. The probability of butt-log quality improvement is very low for sugar maple trees of large diameter. No butt-log quality improvement was computed for trees over 27 inches d.b.h.

Thus once the physical measurements of the future tree are calculated under the preceding predictions, and assuming that the price of 4/4 No. 1 Common lumber and conversion costs remain the same, the future value can be determined from the tree-conversion value table, and the rate of value increase can be obtained by solving the compound-interest formula.

## THE BASIC SITUATION

Given the data already developed, we can now calculate the rate of value increase for the basic situation; that is, a situation in which prices and conversion costs are assumed to remain unchanged over the 10-year period, and conversion costs are determined to be at the median level of $70 per M board feet. This is the situation presented in previous publications on the rate of value increase, thus allowing for comparison between species.

The rates of value increase and the corresponding dollar value increases were calculated by 2-inch classes for trees ranging in size from 12 to 30 inches in d.b.h. For this specific situation in price of 4/4 No. 1 Common lumber and conversion costs, more than a thousand calculations were necessary. It is apparent that such voluminous data must necessarily be summarized.

## The Rate of Value Increase of Individual Trees

Some generalities about the rate of value increase for individual trees as reported in detail in the previous publications have held true for sugar maple trees. They are:

1. The rate of value increase is less for trees with larger diameters and of higher quality. That is, for trees of higher value at the beginning of the period under consideration ($V_0$), we can expect to get lower rates of value increase (r) at the end of the time period (n). There is a point in time at which these high-value trees will fail to produce a rate of value increase equal to the alternative rate of return. This is the point of financial maturity.
2. Trees of higher vigor, which therefore have a greater diameter growth rate, have a higher rate of value increase. Diameter growth is an important contributor to the increase in value, and these calculations place a value on it and serve to substantiate the important silvicultural desirability of selecting trees of high vigor as crop trees.
3. Improvement in tree quality over the 10-year period results in a higher rate of value increase. These calculations indicate not only the improved rate of value increase but also the dollar value of an improvement in quality. The ability to select prospective crop trees, not only on the basis of volume but also for prospective future quality, contributes immeasurably to the financial success of the timber-growing enterprise.
4. Trees with greater merchantable height, or trees that increase in merchantable height, usually have a higher rate of value increase. In some instances, trees will have very low-quality upper logs that have negative values, thus reducing the rate of value increase.

## Expected Rates of Value Increase

What are the rates of value increase we can expect from sugar maple trees of various diameters, which grow at different rates and may or may not improve in quality over the 10-year

Table 3.—Expected rate of value increase for sugar maple trees, price and conversion costs remaining stable [1]

[In percent]

| D.b.h. (inches) | Due to growth only | | | Due to growth and quality increase [2] | | |
|---|---|---|---|---|---|---|
| | Vigor I | Vigor II | Vigor III | Vigor I | Vigor II | Vigor III |
| | | | | $V_1$ | $V_1$ | |
| | PRICE NO. 1C | | | $185/M | $185/M | |
| | CONVERSION COSTS | | | 70/M | 70/M | |
| 12 | — | — | — | 30-60 | 28-57 | 26-54 |
| 14 | 6-12 | 5-8 | 3-7 | 12-26 | 11-24 | 9-21 |
| 16 | 4-11 | 3-8 | 2-6 | 10-19 | 8-18 | 7-15 |
| 18 | 3- 7 | 3-5 | 2-4 | 7-14 | 7-13 | 6-12 |
| 20 | 3- 5 | 2-4 | 1-3 | 6-13 | 6-12 | 5-10 |
| 22 | 2- 4 | 2-3 | 1-3 | 6-10 | 5-10 | 4- 9 |
| 24 | 2- 3 | 1-3 | 1-2 | 5- 9 | 4- 8 | 4- 8 |
| 26 | 2 | 1 | 1 | 4- 7 | 4- 6 | 4- 6 |
| 28 | 1- 2 | 1 | 1 | [3] | [3] | |
| 30 | 1 | 1 | 1 | [4] | [3] | [4] |
| | | | | $V_m$ | $V_1$ | |
| | PRICE NO. 1C | | | $185/M | $185/M | |
| | CONVERSION COSTS | | | 60/M | 60/M | |
| 12 | — | — | — | 17-26 | 15-21 | 14-20 |
| 14 | 6-12 | 4-8 | 3-7 | 11-23 | 9-19 | 8-17 |
| 16 | 4-11 | 3-7 | 2-6 | 9-17 | 7-13 | 6-12 |
| 18 | 3- 7 | 3-5 | 2-4 | 6-13 | 6-11 | 5-10 |
| 20 | 3- 5 | 2-4 | 1-3 | 6-11 | 5-10 | 4- 8 |
| 22 | 2- 4 | 2-3 | 1-3 | 5- 9 | 4- 8 | 4- 8 |
| 24 | 2- 3 | 1-2 | 1-2 | 4- 8 | 3- 7 | 3- 7 |
| 26 | 2 | 1 | 1 | 4- 6 | 3- 6 | 3- 6 |
| 28 | 1- 2 | 1 | 1 | [3] | [3] | |
| 30 | 1- 2 | 1 | 1 | [3] | [3] | |
| | | | | $V_m$ | $V_1$ | |
| | PRICE NO. 1C | | | $185/M | $185/M | |
| | CONVERSION COSTS | | | 80/M | 80/M | |
| 12 | — | — | — | — | — | |
| 14 | 7-13 | 6-9 | 4-7 | 15-81 | 13-77 | 12-74 |
| 16 | 5-11 | 4-8 | 2-6 | 11-34 | 10-32 | 9-29 |
| 18 | 3- 8 | 3-5 | 2-4 | 8-20 | 8-19 | 7-18 |
| 20 | 3- 5 | 2-4 | 1-3 | 7-16 | 6-15 | 5-13 |
| 22 | 3- 4 | 2-4 | 1-3 | 6-13 | 5-12 | 4-11 |
| 24 | 2- 3 | 1-3 | 1-2 | 5-10 | 4- 9 | 4- 9 |
| 26 | 2 | 1 | 1 | 4- 8 | 4- 8 | 4- 7 |
| 28 | 1- 2 | 1 | 1 | [4] | [4] | — |
| 30 | 1- 2 | 1 | 1 | [4] | [4] | |

[1] Based on 4/4 factory-grade lumber recovery. These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

[2] The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio $V_m/V_0$. For this reason butt-log grade-3 logs have not been considered in the estimates "due to growth only".

[3] The high rates of value increase in the 12- to 16-inch diameter classes are due to two factors: (1) the butt-log grade-3 trees becoming positive in present value, and (2) the improvement of butt-log grade-3 to butt-log grade-2.

[4] No quality improvement in trees larger than 27 inches d.b.h.

period? The answer to this question is provided in table 3, in which are summarized the expected rates for the situation in which both the price of 4/4 No. 1 Common lumber and the conversion costs of $70 per M board feet remain stable throughout the 10-year period.

The expected rates of value increase are presented as a range of rates by 2-inch d.b.h classes for each of the three vigor classes. Further, table 3 is subdivided into two sections, which present the rates for trees in which growth alone is expected and for trees in which both growth and improvement in quality are expected over the 10-year period.

Two features of the table are especially noteworthy. First, note the decreasing rates as diameters of the trees increase. Trees 24 inches d.b.h. and over, with growth only, earn at best a rate of value increase of 3 percent. Second, note the increase in the rate when an improvement in quality occurs over the 10-year period. This again emphasizes the importance of identifying trees with potential grade improvement when marking the stand for cutting or when selecting crop trees.

An expanded version of the expected rate of value increase for this basic situation appears in table 9 (in appendix).

## Financial-Maturity Marking Guide

The rate of value increase is a measure of a tree's earning power. It can be used to develop marking guides for selection cutting under uneven-aged systems and for improvement cutting in previously unmanaged stands. The guide is presented in tabular form for the alternative rates of return of 2, 4, and 6 percent and for each of the three vigor classes (table 4).

The diameters shown are the maximums that will earn the indicated interest rates over the next 10 years. Trees grown to diameters greater than indicated will fail to produce the alternative rate of return. Note that this table is based on diameter growth alone. Where grade improvement or log-height increase is probable over the next 10 years, these diameters should be adjusted upward. When using financial maturity as a guide to harvesting, give full consideration to silvicultural and management requirements.

Table 4.—Sugar Maple diameters for financial maturity, based on value increase determined by diameter growth alone[1]

[In inches]

| Vigor class | Percent return | | |
|---|---|---|---|
| | 2 | 4 | 6 |
| | | $V_o$ | $V_n$ |
| PRICE NO. 1C LUMBER | | $185/M | $185/M |
| CONVERSION COSTS | | 70/M | 70/M |
| I | 27 | 19 | 16 |
| II | 23 | 16 | 14 |
| III | 20 | 14 | — |
| | | $V_o$ | $V_n$ |
| PRICE NO. 1C LUMBER | | $185/M | $185/M |
| CONVERSION COSTS | | 60/M | 60/M |
| I | 26 | 18 | 15 |
| II | 22 | 16 | 14 |
| III | 20 | 14 | — |
| | | $V_o$ | $V_n$ |
| PRICE NO. 1C LUMBER | | $185/M | $185/M |
| CONVERSION COSTS | | 80/M | 80/M |
| I | 27 | 20 | 17 |
| II | 24 | 18 | 15 |
| III | 22 | 16 | 14 |
| | | $V_o$ | $V_n$ |
| PRICE NO. 1C LUMBER | | $185/M | $185/M |
| CONVERSION COSTS | | 70/M | 60/M |
| I | 29 | 20 | 16 |
| II | 25 | 18 | 15 |
| III | 23 | 15 | 13 |
| | | $V_o$ | $V_n$ |
| PRICE NO. 1C LUMBER | | $185/M | $195/M |
| CONVERSION COSTS | | 70/M | 80/M |
| I | 24 | 17 | 14 |
| II | 22 | 15 | 13 |
| III | 18 | — | — |
| | | $V_o$ | $V_n$ |
| PRICE NO. 1C LUMBER | | $185/M | $195/M |
| CONVERSION COSTS | | 70/M | 60/M |
| I | 32 | 22 | 17 |
| II | 30 | 20 | 16 |
| III | 29 | 18 | 15 |

[1] Based on trees with butt-log grades of 1 and 2.

## Dollar Value Increase

Some forest land managers may have a greater concern for the dollar earning capacity of their holdings than for the rate of value in-

crease. The actual dollar increases in conversion value to be expected over a 10-year period through increases in diameter, merchantable height, and quality improvement are presented in table 10 (in appendix).

In general, trees with larger diameters, greater merchantable heights, or higher log quality will have greater *dollar* value increases during the 10-year period (fig. 2).

This is opposite of what was true for the rate of value increase. For trees of larger diameters, of greater merchantable height, or of higher quality, we can expect that the *rates* of value increase will be lower for the 10-year period (fig. 3).

You must understand the difference between the *dollar value* increase table and the *rate of value* increase tables. The *dollar value* increase tables account for the increases in the value of the tree because of the additional value that results from expected increases in diameter, merchantable height, or improvement in quality. The *rate of value* increase table, on the other hand, accounts for the initial investment in capital (the value of the tree at the beginning of the 10-year period) that must be made to attain the dollar value increase (value added at the end of the 10-year period). The rate of return on the investment (rate of value increase) over the 10-year period is determined by the relationship between the values at the beginning and end of the time period.

Figure 2.—Relation of dollar value increase to d.b.h. over a 10-year period. Based on trees of vigor 1, butt-log grade 1, and 32 feet merchantable height.

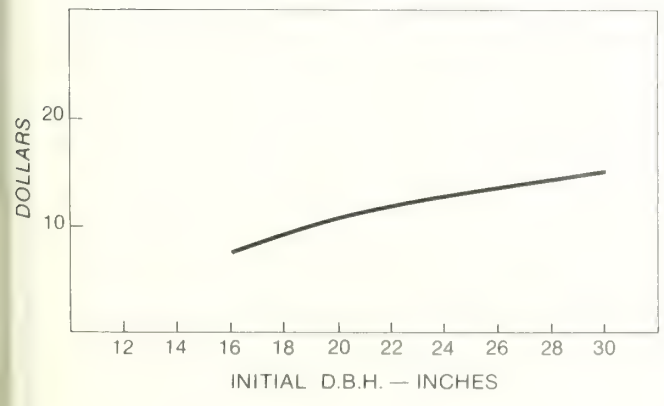
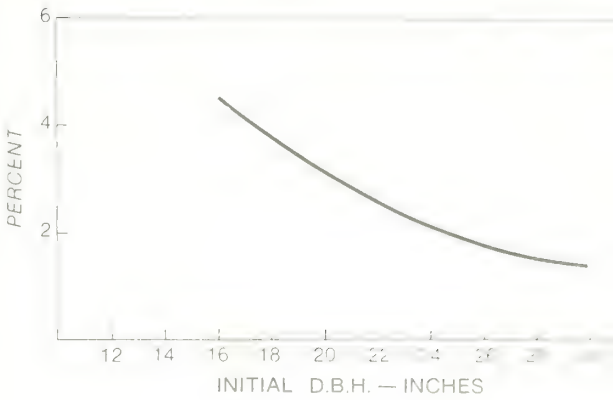



Figure 3.—Relation of rate of value increase to d.b.h.




It is the timberland owner alone who must determine the financial objectives of his ownership. Will it be dollar value increase regardless of the amount of capital investment? Or will it be a prescribed rate of return on the capital investment?

## THE RATE OF VALUE INCREASE IN A DYNAMIC MARKET SITUATION

The basic situation we have discussed portrays only one of the many real-life situations encountered in a dynamic market. We can expect to have fluctuations, both up and down, in the price of No. 1 Common lumber and conversion costs over the 10-year period. How these fluctuations affect the expected rate of value increase and the financial-maturity diameters are worth further consideration.

We modified our procedure (fig. 1) to account for prospective changes in price and costs (fig. 4). This adaptation did not require any great change in methodology. All that was necessary was an additional series of separate calculations based on the new price and conversion cost to determine the future tree-conversion value. The important factor is the influence of costs and price on the rate of value increase and what it means in terms of financial maturity.

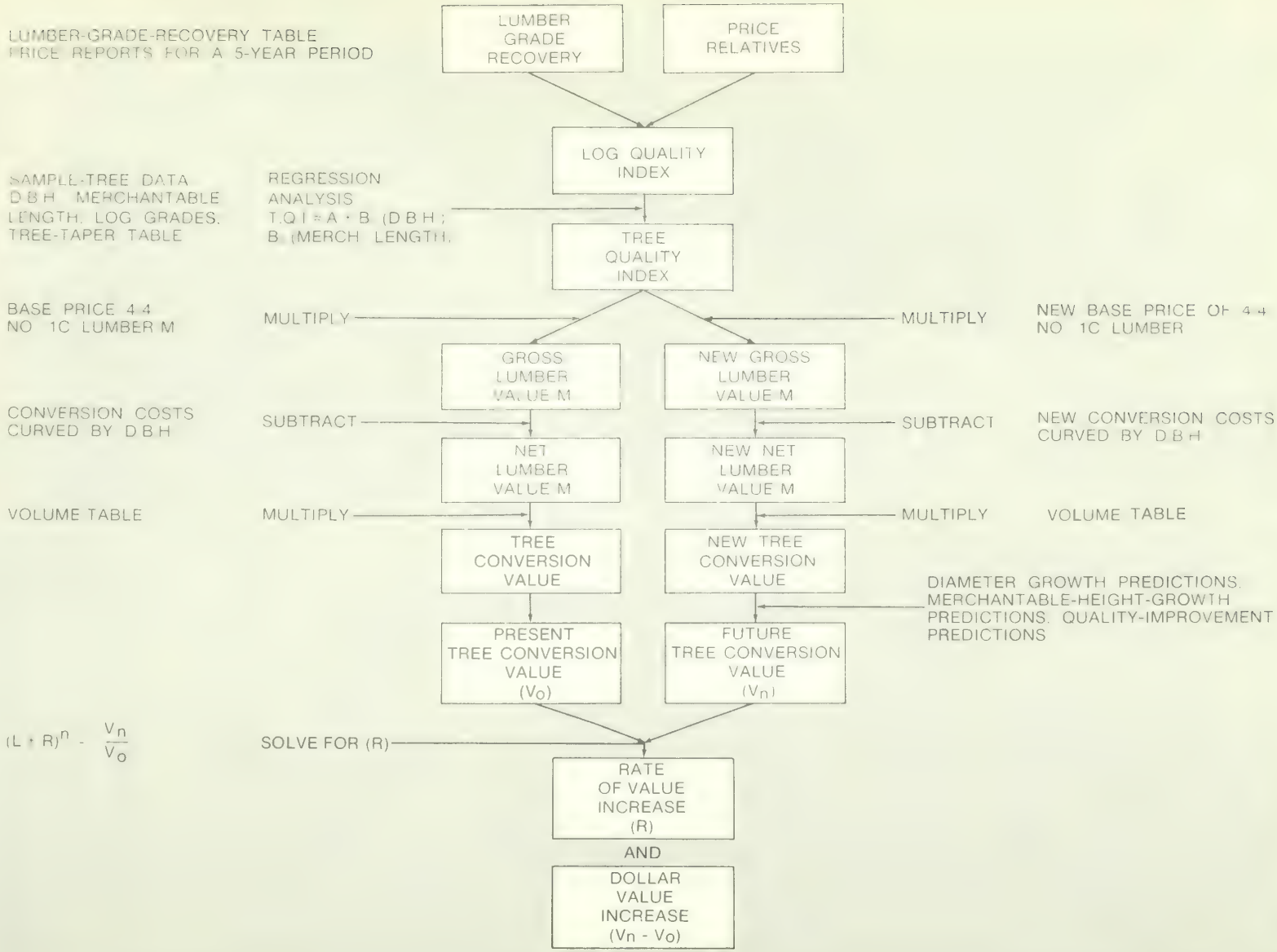



Figure 4.—Calculation of rate of value increase under a situation of changing prices and conversion costs.

## The Influence of Conversion Cost

Of all the factors that bear on the rate of value increase, the one most subject to manipulation and change is conversion cost. Standing timber trees of the same size and quality may not necessarily have the same value because of the conversion costs involved. Location of the timber tract, difficulties of logging, proximity to roads and mills, and efficiency of the mills all play a role in determining the value of the timber and the return on the capital that the owner has invested in the standing timber. One can easily conceive of a rather large number of different conversion costs generated by a variety of combinations of such factors.

It is for this reason that we have shown three levels of conversion costs (table 2), which we hope encompass the wide spectrum of possible costs. We wanted to illustrate the influence of these different levels of cost on the rate of value increase and on financial maturity diameters. So we investigated the rates and diameters resulting from two situations in which the conversion-cost levels were at $60 and $80 per M board feet and remained stable throughout the entire 10-year period (tables 3 and 4).

We should also mention that the basic situation, which we previously discussed in detail, is a similar situation, with conversion costs at the $70 level (tables 3 and 4).

An analysis of the expected rates of value increase for these three situations reveals a unique relationship between conversion costs and the rate of value increase, which is not readily apparent nor eminently logical. The lower the conversion costs (as long as they remain the same at the beginning and end of the period), the lower the rate of value increase. And conversely, the higher the conversion costs, the higher the rates of value increase. What actually occurs is that lower conversion costs result in higher value of the standing timber, with a resulting increased capital investment carried on through the 10-year period and, therefore, a lower rate of value increase. The absolute reverse is true for higher conversion costs.

Table 3 indicates that for every $10 per M board feet increase in conversion costs, there is 1-percent or less increase in the expected rate of value increase. These increases are especially small in the 24- to 30-inch diameter classes, in which the expected rates in the "due-to-growth only" section are almost identical for all three levels of conversion costs.

The influence of conversion costs is somewhat more evident in the financial-maturity tables (table 4). For every $10 per M board feet increase in conversion costs, financial-maturity diameters increase about 1 inch, indicating that in stands with higher conversion costs—such as in remote areas or with steeper slopes or with longer hauls to the mills—the trees would be retained to larger sizes to reach financial maturity.

We investigated one other situation regarding conversion costs: a reduction of $10 per M board feet *during* the 10-year period (table 5). Logically, such a reduction could occur as a result of efficiencies in harvesting or in transportation, or as a result of innovations in milling. The effect is an improvement of 1 to 3 percent in the expected rate of value increase as compared to that of the basic situation. The improvement would be inversely proportional to the d.b.h. of the tree. That is, as the d.b.h. increases, the magnitude of the improvement decreases. In sugar maple trees of 20 inches d.b.h. or larger, the differences between the two situations amount to 1 percent (table 5).

This reduction of $10 per M board feet in conversion costs also has a significant effect on financial-maturity diameters. When these diameters are the guiding influence in determining the maturity of sugar maple trees or stands, the advantages of a reduction in conversion costs are evident. Sugar maple trees under such a situation can be grown to a larger diameter before they achieve financial maturity. Increases of 1 to 3 inches in d.b.h. are calculated for the different alternative rates of return as compared to those in the basic situation (table 4).

## The Influence of Prices

The price of 4/4 No. 1 Common lumber is also an influencing factor in determining financial maturity of timber trees and stands. However, it is considerably different from conversion costs. For the most part, it is beyond the control of the timber grower, operator, or saw-

Table 5—Expected rate of value increase for sugar maple trees, price remaining stable but conversion costs decreasing [1]

[In percent]

| D.b.h. (inches) | Due to growth only | | | Due to growth and quality increase[2] | | |
|---|---|---|---|---|---|---|
| | Vigor I | Vigor II | Vigor III | Vigor I | Vigor II | Vigor III |
| 12 | — | — | — | [3]33-64 | 31-61 | 29-59 |
| 14 | 8-15 | 7-11 | 6-9 | 14-29 | 12-27 | 11-24 |
| 16 | 6-13 | 5- 8 | 4-8 | 11-21 | 10-20 | 9-17 |
| 18 | 5- 9 | 4- 7 | 3-6 | 9-16 | 8-15 | 7-14 |
| 20 | 4- 6 | 3- 5 | 3-5 | 8-15 | 7-14 | 6-12 |
| 22 | 3- 5 | 3- 5 | 2-4 | 6-12 | 6-11 | 5-11 |
| 24 | 3- 4 | 2- 4 | 2-3 | 6-10 | 5- 9 | 4- 9 |
| 26 | 2- 3 | 2- 3 | 2-2 | 5- 8 | 4- 8 | 4- 8 |
| 28 | 2- 3 | 2- 2 | 1-2 | ([4]) | ([4]) | ([4]) |
| 30 | 2- 3 | 1- 2 | 1-2 | ([4]) | ([4]) | ([4]) |

[1] Based on 4/4 factory-grade lumber recovery under the following circumstances:

| | $V_o$ | $V_n$ |
|---|---|---|
| Price No. 1C — | $185/M | $185/M |
| Conversion costs — | 70/M | 60/M |

These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

[2] The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio $V_n/V_o$. For this reason butt-log grade-3 logs have not been considered in the estimates "due to growth only".

[3] The high rates of value increase in the 12- and 14-inch diameter classes are due to two factors: (1) the butt-log grade-3 trees becoming positive in present value, and (2) the improvement of butt-log grade-3 trees to butt-log grade-2.

[4] No quality improvement in trees larger than 27 inches d.b.h.

mill man, as it is subject to the intricacies of supply and demand of the market place.

The effect of a price increase is similar to a reduction in conversion costs. An increase of $10 per M board feet in the price of 4/4 No. 1 Common lumber would have an effect on financial maturity similar to that of a reduction of $10 per M board feet in conversion costs. Either of these changes, occurring during the 10-year period, would result in an improvement in the rate of value increase.

So rather than duplicate the findings we had in our analysis of conversion costs, we extended our investigation to include two situations in which both price and conversion costs changed during the 10-year period (tables 6 and 7).

The first analysis depicts a situation that would occur during an inflationary period characterized by rising lumber prices as well as increased conversion costs. We assumed that both lumber prices and conversion costs would increase by $10 per M board feet. The expected rates of value increase under such assumptions would be about 1 percent less than those calculated in our basic situation of stable price and conversion costs. Also, financial-maturity diameters would be reduced by 1 to 2 inches. Thus, in this inflationary situation under which lumber prices rose only 5.4 percent and conversion costs rose 14.3 percent, standing timber would approach financial maturity at an earlier date, and diameter limits would be lower than those calculated for a stable economy.

A number of different situations with rising prices and conversion costs can easily be visualized to which a rule of thumb can be applied. When a combination of rising lumber prices and conversion costs are such that the net value of the lumber is reduced (as in the above situation), financial maturity is at an earlier period and financial maturity diameters are lower. When the combination of lumber prices and conversion costs are such that the net value of the lumber is increased, financial maturity is at a later period and financial-maturity diameters are higher than those of the basic situation.

The second situation we investigated was a rather idealistic one. Prices were assumed to

Table 6.—Expected rate of value increase for sugar maple trees, prices and conversion costs increasing [1]

[In percent]

| D.b.h. (inches) | Due to growth only | | | Due to growth and quality increase[2] | | |
|---|---|---|---|---|---|---|
| | Vigor I | Vigor II | Vigor III | Vigor I | Vigor II | Vigor III |
| 12 | — | — | — | [3]29-58 | 27-54 | 25-52 |
| 14 | 5-11 | 4-7 | 2-6 | 12-24 | 10-23 | 9-20 |
| 16 | 4-10 | 3-7 | 2-6 | 9-18 | 8-16 | 7-14 |
| 18 | 3- 7 | 2-5 | 2-4 | 7-14 | 6-12 | 5-11 |
| 20 | 3- 4 | 2-3 | 1-3 | 6-12 | 5-11 | 4- 9 |
| 22 | 2- 4 | 2-3 | 1-3 | 5-10 | 5- 9 | 4- 9 |
| 24 | 2- 3 | 1-2 | 1-2 | 4- 8 | 4- 8 | 3- 7 |
| 26 | 2- 2 | 1-1 | 1-1 | 4- 7 | 3- 6 | 3- 6 |
| 28 | 1- 2 | 1-1 | 1-1 | (4) | [illegible] | [illegible] |
| 30 | 1- 2 | 1-1 | 1-1 | (4) | [illegible] | [illegible] |

[1] Based on 4/4 factory-grade lumber recovery under the following circumstances:

| | $V_o$ | $V_n$ |
|---|---|---|
| Price No. 1C — | $185/M | $195/M |
| Conversion costs — | 70/M | 80/M |

These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

[2] The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio $V_n/V_o$. For this reason butt-log grade-3 logs have not been considered in the estimates "due to growth only".

[3] The high rates of value increase in the 12- and 14-inch diameter classes are due to two factors: (1) the butt-log grade-3 trees becoming positive in present value, and (2) the improvement of butt-log grade-3 trees to butt-log grade-2.

[4] No quality improvement in trees larger than 27 inches d.b.h.

Table 7.—Expected rate of value increase for sugar maple trees, prices increasing and conversion costs decreasing [1]

[In percent]

| D.b.h. (inches) | Due to growth only | | | Due to growth and quality increase[2] | | |
|---|---|---|---|---|---|---|
| | Vigor I | Vigor II | Vigor III | Vigor I | Vigor II | Vigor III |
| 12 | — | — | — | [3]35-66 | 33-63 | 31-61 |
| 14 | 9-16 | 8-12 | 7-11 | 15-30 | 13-28 | 12-25 |
| 16 | 6-14 | 6-10 | 4- 9 | 12-22 | 11-21 | 10-18 |
| 18 | 6-10 | 5- 8 | 4- 7 | 9-17 | 9-16 | 8-15 |
| 20 | 5- 7 | 4- 6 | 3- 6 | 9-16 | 8-15 | 7-13 |
| 22 | 4- 6 | 3- 6 | 3- 5 | 7-13 | 6-12 | 6-12 |
| 24 | 3- 5 | 3- 5 | 2- 4 | 6-11 | 6-10 | 5-10 |
| 26 | 3- 4 | 3- 3 | 2- 3 | 6- 9 | 5- 9 | 5- 8 |
| 28 | 3- 4 | 2- 3 | 2- 3 | (4) | [illegible] | [illegible] |
| 30 | 3- 3 | 2- 3 | 2- 3 | (4) | [illegible] | [illegible] |

[1] Based on 4/4 factory-grade lumber recovery under the following circumstances:

| | $V_o$ | $V_n$ |
|---|---|---|
| Price No. 1C — | $185/M | $195/M |
| Conversion costs — | 70/M | 60/M |

These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

[2] The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio $V_n/V_o$. For this reason butt-log grade-3 logs have not been considered in the estimates "due to growth only".

[3] The high rates of value increase in the 12- and 14-inch diameter classes are due to two factors: (1) the butt-log grade-3 trees becoming positive in present value, and (2) the improvement of butt-log grade-3 trees to butt-log grade-2.

[4] No quality improvement in trees larger than 27 inches d.b.h.

rise by $10 per M board feet, while conversion costs were reduced by $10 per M board feet. Such a situation could possibly be achieved through the introduction of efficient timber-harvesting machinery and mill innovations. Under this situation, the expected rates of value increase were the greatest (table 7). Improvements of 1 to 3 percent over those of the basic situation were calculated. Considerable increases were recorded in financial-maturity diameters (table 4)—from 1 to 9 inches, indicating that financial maturity for trees and stands under this idealistic situation is arrived at after a longer perod.

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■

# APPENDIX

Table 8.—Ten-year d.b.h. growth rate for sugar maple, in inches

| D.b.h. (inches) | Vigor I | Vigor II | Vigor III & IV |
|---|---|---|---|
| 12.0 | 2.4 | 1.8 | 1.3 |
| 14.0 | 2.2 | 1.7 | 1.2 |
| 16.0 | 2.1 | 1.6 | 1.1 |
| 18.0 | 2.0 | 1.5 | 1.1 |
| 20.0 | 1.9 | 1.4 | 1.0 |
| 22.0 | 1.8 | 1.3 | 1.0 |
| 24.0 | 1.7 | 1.2 | .9 |
| 26.0 | 1.6 | 1.1 | .9 |
| 28.0 | 1.5 | 1.0 | .8 |
| 30.0 | 1.4 | .9 | .8 |

Table 9.—Ten-year rate of value increase for sugar maple, in percent

| D.b.h. inches | Butt log grade | Merchantable height feet | Initial value dollars | Vigor I | | | | | | Vigor II | | | | | | Vigor III | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No change in butt log grade with height increase of | | | Increase in butt log grade with height increase of | | | No change in butt log grade with height increase of | | | Increase in butt log grade with height increase of | | | No change in butt log grade with height increase of | | | Increase in butt log grade with height increase of | | |
| | | | | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 |
| 12 | 2 | 16 | 1.44 | 7.1 | 10.8 | 12.9 | 14.5 | 18.0 | 19.6 | 5.3 | 8.7 | 10.7 | 12.9 | 16.1 | 17.7 | 3.8 | 6.9 | 8.8 | 11.6 | 14.4 | 16.0 |
| | | 24 | 1.78 | 8.5 | 10.5 | — | 15.5 | 17.1 | — | 6.5 | 8.5 | — | 13.7 | 15.2 | — | 4.7 | 6.6 | — | 12.1 | 13.6 | — |
| | | 32 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 12 | 3 | 16 | .21 | 18.4 | 20.4 | 19.7 | 30.1 | 34.6 | 37.1 | 15.0 | 16.0 | 13.9 | 28.0 | 32.1 | 34.6 | 11.7 | 11.5 | 7.3 | 26.1 | 29.9 | 32.3 |
| | | 24 | .04 | 40.2 | 39.3 | — | — | — | — | 35.0 | 32.7 | — | — | — | — | 29.8 | 24.9 | — | — | — | — |
| | | 32 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 12 | 4 | 16 | .00 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | 24 | .00 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | 32 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 14 | 2 | 16 | 2.56 | 6.3 | 9.9 | 12.1 | 12.8 | 16.1 | 18.0 | 4.8 | 8.4 | 10.7 | 11.5 | 14.8 | 16.6 | 3.4 | 7.0 | 9.1 | 10.2 | 13.5 | 15.2 |
| | | 24 | 3.57 | 6.3 | 8.5 | 9.6 | 12.4 | 14.2 | 14.7 | 4.9 | 7.1 | 8.2 | 11.1 | 12.8 | 13.4 | 3.5 | 5.6 | — | 9.8 | 11.5 | — |
| | | 32 | 4.26 | 6.6 | 7.7 | — | 12.1 | 12.7 | — | 5.2 | 6.3 | — | 10.8 | 11.3 | — | 3.7 | — | — | 9.5 | — | — |
| | | 40 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 14 | 3 | 16 | .92 | 9.8 | 12.4 | 13.4 | 17.8 | 21.7 | 24.2 | 7.7 | 10.2 | 10.9 | 16.2 | 20.1 | 22.6 | 5.6 | 7.9 | 8.2 | 14.6 | 18.5 | 20.9 |
| | | 24 | 1.04 | 11.1 | 12.1 | 11.6 | 20.3 | 22.7 | 24.1 | 8.8 | 9.6 | 8.8 | 18.6 | 21.1 | 22.4 | 6.6 | 6.9 | — | 17.1 | 19.4 | — |
| | | 32 | .91 | 13.6 | 13.1 | — | 24.4 | 25.7 | — | 11.1 | 10.3 | — | 22.8 | 24.1 | — | 8.4 | — | — | 21.1 | — | — |
| | | 40 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 14 | 4 | 16 | .00 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | 24 | .00 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | 32 | .00 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | 40 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 16 | 1 | 16 | 8.20 | 4.6 | 7.7 | 9.3 | — | — | — | 3.6 | 6.6 | 8.2 | — | — | — | 2.6 | 5.5 | 7.0 | — | — | — |
| | | 24 | 10.89 | 4.7 | 6.2 | 6.9 | — | — | — | 3.6 | 5.1 | 5.8 | — | — | — | 2.6 | 4.0 | 4.7 | — | — | — |
| | | 32 | 12.81 | 4.5 | 5.2 | 5.7 | — | — | — | 3.4 | 4.1 | 4.7 | — | — | — | 2.3 | 3.0 | — | — | — | — |
| | | 40 | 13.43 | 4.7 | 5.2 | — | — | — | — | 3.6 | 4.2 | — | — | — | — | 2.5 | — | — | — | — | — |
| | | 48 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 16 | 2 | 16 | 4.48 | 5.3 | 8.8 | 10.8 | 11.1 | 14.4 | 16.1 | 4.1 | 7.5 | 9.6 | 10.1 | 13.2 | 14.9 | 3.0 | 6.3 | 8.3 | 9.0 | 12.1 | 13.7 |
| | | 24 | 6.20 | 5.3 | 7.3 | 8.6 | 10.7 | 12.4 | 13.1 | 4.1 | 6.1 | 7.4 | 9.6 | 11.2 | 12.0 | 2.9 | 4.8 | 6.1 | 8.5 | 10.0 | 10.8 |
| | | 32 | 7.66 | 5.1 | 6.3 | 7.5 | 10.0 | 10.8 | 11.3 | 3.9 | 5.1 | 6.4 | 8.9 | 9.6 | 10.2 | 2.6 | 3.9 | — | 7.7 | 8.4 | — |
| | | 40 | 8.59 | 5.2 | 6.4 | — | 9.6 | 10.2 | — | 4.0 | 5.3 | — | 8.5 | 9.1 | — | 2.8 | — | — | 7.3 | — | — |
| | | 48 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 16 | 3 | 16 | 2.17 | 7.0 | 9.9 | 11.2 | 13.2 | 16.9 | 19.2 | 5.5 | 8.2 | 9.4 | 12.0 | 15.6 | 17.8 | 4.0 | 6.5 | 7.6 | 10.7 | 14.3 | 16.4 |
| | | 24 | 2.73 | 7.4 | 8.7 | 9.1 | 14.3 | 16.5 | 17.9 | 5.8 | 7.0 | 7.3 | 13.0 | 15.2 | 16.6 | 4.2 | 5.2 | 5.3 | 11.7 | 13.8 | 15.2 |
| | | 32 | 2.98 | 7.8 | 8.1 | 8.3 | 15.5 | 16.8 | 18.1 | 6.1 | 6.3 | 6.3 | 14.2 | 15.5 | 17.9 | 4.2 | 4.4 | — | 12.8 | 14.2 | — |
| | | 40 | 2.82 | 8.7 | 8.9 | — | 17.5 | 18.8 | — | 6.9 | 6.9 | — | 16.2 | 17.5 | — | 4.9 | — | — | 14.8 | — | — |
| | | 48 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 18 | 1 | 16 | 12.69 | 3.8 | 6.8 | 8.4 | — | — | — | 2.8 | 5.8 | 7.4 | — | — | — | 2.1 | 5.1 | 6.6 | — | — | — |
| | | 24 | 16.83 | 3.8 | 5.4 | 6.0 | — | — | — | 2.9 | 4.4 | 5.1 | — | — | — | 2.2 | 3.7 | 4.4 | — | — | — |
| | | 32 | 19.48 | 3.8 | 4.5 | 5.1 | — | — | — | 2.9 | 3.6 | 4.2 | — | — | — | 2.1 | 2.9 | 3.4 | — | — | — |
| | | 40 | 20.89 | 3.8 | 4.4 | 3.8 | — | — | — | 2.9 | 3.5 | — | — | — | — | 2.2 | 2.7 | — | — | — | — |
| | | 48 | 22.00 | 3.9 | 3.3 | — | — | — | — | 2.9 | — | — | — | — | — | 2.2 | — | — | — | — | — |
| | | 56 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 18 | 2 | 16 | 7.36 | 4.3 | 7.7 | 9.7 | 9.6 | 12.7 | 14.4 | 3.2 | 6.6 | 8.6 | 8.6 | 11.8 | 13.4 | 2.4 | 5.8 | 7.7 | 7.8 | 11.0 | 12.6 |
| | | 24 | 10.14 | 4.3 | 6.2 | 7.4 | 9.2 | 10.8 | 11.6 | 3.2 | 5.2 | 6.4 | 8.3 | 9.8 | 10.6 | 2.4 | 4.3 | 5.6 | 7.5 | 9.0 | 9.8 |
| | | 32 | 12.27 | 4.2 | 5.4 | 6.6 | 8.8 | 9.5 | 10.1 | 3.2 | 4.4 | 5.5 | 7.8 | 8.5 | 9.1 | 2.4 | 3.6 | 4.7 | 7.0 | 7.7 | 8.3 |
| | | 40 | 13.84 | 4.1 | 5.3 | 5.3 | 8.1 | 8.8 | 8.2 | 3.2 | 4.3 | — | 7.2 | 7.8 | — | 2.3 | 3.4 | — | 6.4 | 7.0 | — |
| | | 48 | 15.47 | 4.1 | 4.1 | — | 7.6 | 7.0 | — | 3.1 | — | — | 6.6 | — | — | 2.3 | — | — | 5.8 | — | — |
| | | 56 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 18 | 3 | 16 | 4.17 | 5.3 | 8.2 | 9.8 | 10.4 | 14.0 | 16.1 | 4.0 | 6.9 | 8.4 | 9.2 | 12.8 | 15.0 | 3.0 | 5.9 | 7.2 | 8.4 | 12.0 | 14.0 |
| | | 24 | 5.41 | 5.5 | 6.9 | 7.5 | 11.0 | 13.1 | 14.4 | 4.2 | 5.6 | 6.2 | 9.9 | 12.0 | 13.3 | 3.1 | 4.5 | 5.1 | 9.1 | 11.1 | 12.4 |
| | | 32 | 6.09 | 5.7 | 6.3 | 6.8 | 11.8 | 13.0 | 14.3 | 4.3 | 4.9 | 5.3 | 10.7 | 12.0 | 13.2 | 3.2 | 3.8 | 4.1 | 9.8 | 11.1 | 12.3 |
| | | 40 | 6.32 | 5.9 | 6.4 | 5.6 | 12.6 | 13.9 | 13.9 | 4.5 | 4.9 | — | 11.6 | 12.8 | — | 3.4 | 3.7 | — | 10.7 | 11.9 | — |
| | | 48 | 6.37 | 6.3 | 5.5 | — | 13.8 | 13.8 | — | 4.8 | — | — | 12.7 | — | — | 3.6 | — | — | 11.8 | — | — |
| | | 56 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 20 | 1 | 16 | 18.46 | 3.1 | 6.0 | 7.7 | — | — | — | 2.4 | 5.2 | 6.8 | — | — | — | 1.7 | 4.5 | 6.2 | — | — | — |
| | | 24 | 24.52 | 3.0 | 4.7 | 5.4 | — | — | — | 2.3 | 3.8 | 4.6 | — | — | — | 1.6 | 3.2 | 3.9 | — | — | — |
| | | 32 | 28.40 | 3.1 | 3.9 | 4.7 | — | — | — | 2.3 | 3.0 | 3.8 | — | — | — | 1.7 | 2.4 | 3.1 | — | — | — |
| | | 40 | 30.27 | 3.2 | 4.0 | 3.7 | — | — | — | 2.4 | 3.2 | 2.8 | — | — | — | 1.7 | 2.4 | 2.0 | — | — | — |
| | | 48 | 32.15 | 3.4 | 3.1 | 3.2 | — | — | — | 2.5 | 2.1 | 2.3 | — | — | — | 1.8 | 1.4 | — | — | — | — |
| | | 56 | 30.33 | 3.7 | 3.9 | — | — | — | — | 2.7 | 2.9 | — | — | — | — | 2.0 | — | — | — | — | — |
| | | 64 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 2 | 16 | 11.18 | 3.5 | 6.7 | 8.8 | 8.4 | 11.5 | 13.2 | 2.6 | 5.8 | 7.9 | 7.6 | 10.6 | 12.3 | 1.9 | 5.1 | 7.2 | 6.9 | 10.1 | 11.8 |
| | | 24 | 15.40 | 3.4 | 5.4 | 6.6 | 8.0 | 9.6 | 10.5 | 2.5 | 4.5 | 5.6 | 7.1 | 8.8 | 9.5 | 1.8 | 3.8 | 4.9 | 6.5 | 8.3 | 9.0 |
| | | 32 | 18.56 | 3.4 | 4.6 | 5.9 | 7.6 | 8.4 | 9.2 | 2.5 | 3.7 | 5.0 | 6.8 | 7.5 | 8.3 | 1.9 | 3.0 | 4.2 | 6.1 | 6.8 | 7.8 |
| | | 40 | 20.71 | 3.5 | 4.7 | 5.0 | 7.2 | 8.0 | 7.7 | 2.5 | 3.8 | 4.0 | 6.3 | 7.1 | 6.7 | 1.8 | 3.1 | 3.2 | 5.7 | 6.4 | 6.1 |
| | | 48 | 23.17 | 3.6 | 3.8 | 4.6 | 6.8 | 6.5 | 6.7 | 2.7 | 2.8 | 3.7 | 5.9 | 5.5 | 5.7 | 1.9 | 2.0 | – | 5.2 | 4.7 | |
| | | 56 | 23.21 | 3.8 | 4.6 | | 6.5 | 6.7 | | 2.8 | 3.6 | | 5.5 | 5.7 | | 2.0 | – | | 4.7 | | |
| | | 64 | — | – | | | | | | — | | | | | | | | | | | |
| 20 | 3 | 16 | 6.98 | 4.1 | 7.0 | 8.7 | 8.5 | 11.9 | 14.0 | 3.1 | 6.0 | 7.6 | 7.6 | 10.9 | 13.1 | 2.2 | 5.1 | 6.7 | 6.8 | 10.2 | 12.3 |
| | | 24 | 9.21 | 4.1 | 5.7 | 6.6 | 8.8 | 10.9 | 12.2 | 3.1 | 4.7 | 5.4 | 7.9 | 10.0 | 11.2 | 2.2 | 3.8 | 4.4 | 7.2 | 9.3 | 10.4 |
| | | 32 | 10.58 | 4.3 | 5.1 | 5.9 | 9.4 | 10.7 | 12.0 | 3.2 | 3.9 | 4.7 | 8.5 | 9.7 | 11.0 | 2.4 | 3.0 | 3.7 | 7.7 | 8.9 | 10.2 |
| | | 40 | 11.17 | 4.5 | 5.3 | 5.0 | 10.1 | 11.4 | 11.6 | 3.3 | 4.1 | 3.7 | 9.1 | 10.4 | 10.6 | 2.4 | 3.1 | 2.6 | 8.3 | 9.6 | 9.8 |
| | | 48 | 11.73 | 4.8 | 4.5 | 4.7 | 10.9 | 11.1 | 12.0 | 3.6 | 3.2 | 3.4 | 9.9 | 10.1 | 11.0 | 2.6 | 2.1 | | 9.1 | 9.2 | – |
| | | 56 | 10.91 | 5.2 | 5.5 | — | 11.9 | 12.8 | | 3.9 | 4.1 | | 10.9 | 11.8 | — | 2.9 | | | 10.0 | | |
| | | 64 | | | | | | | | | | | | | | | | | | | |
| 22 | 1 | 16 | 25.52 | 2.6 | 5.3 | 7.1 | | | | 2.0 | 4.7 | 6.4 | | | | 1.6 | 4.3 | 6.0 | | | |
| | | 24 | 33.62 | 2.5 | 4.2 | 5.1 | | | | 1.8 | 3.5 | 4.4 | | | – | 1.4 | 3.1 | 3.9 | | | |
| | | 32 | 39.30 | 2.6 | 3.5 | 4.4 | | | | 1.9 | 2.7 | 3.6 | | | | 1.5 | 2.3 | 3.2 | | | |
| | | 40 | 42.32 | 2.7 | 3.6 | 3.5 | | | — | 2.0 | 2.9 | 2.8 | | | | 1.5 | 2.4 | 2.3 | | | |
| | | 48 | 45.65 | 2.9 | 2.8 | 3.1 | | | | 2.1 | 2.0 | 2.2 | | | | 1.6 | 1.5 | 1.7 | | | |
| | | 56 | 44.32 | 3.1 | 3.4 | 3.4 | | | | 2.3 | 2.5 | | | | | 1.8 | 2.0 | | | | |
| | | 64 | 45.19 | 3.2 | | | | | | 2.3 | | | | | | 1.8 | | | | | |
| 22 | 2 | 16 | 15.99 | 2.9 | 5.9 | 8.0 | 7.5 | 10.4 | 12.0 | 2.1 | 5.2 | 7.3 | 6.9 | 9.7 | 11.5 | 1.7 | 4.8 | 6.8 | 6.4 | 9.3 | 11.1 |
| | | 24 | 21.78 | 2.7 | 4.7 | 6.1 | 7.0 | 8.8 | 9.8 | 2.0 | 4.0 | 5.3 | 6.3 | 8.1 | 9.0 | 1.6 | 3.6 | 4.8 | 5.9 | 7.7 | 8.5 |
| | | 32 | 26.42 | 2.7 | 4.1 | 5.4 | 6.7 | 7.7 | 8.7 | 2.1 | 3.3 | 4.6 | 6.0 | 6.9 | 7.8 | 1.6 | 2.8 | 4.2 | 5.6 | 6.4 | 7.4 |
| | | 40 | 29.63 | 2.9 | 4.2 | 4.6 | 6.5 | 7.4 | 7.3 | 2.1 | 3.4 | 3.8 | 5.7 | 6.6 | 6.5 | 1.6 | 3.0 | 3.3 | 5.2 | 6.1 | 6.0 |
| | | 48 | 33.48 | 3.0 | 3.3 | 4.2 | 6.1 | 6.0 | 6.3 | 2.2 | 2.6 | 3.4 | 5.3 | 5.2 | 5.4 | 1.7 | 2.0 | 2.9 | 4.8 | 4.7 | 4.9 |
| | | 56 | 34.25 | 3.1 | 4.0 | | 5.8 | 6.1 | | 2.3 | 3.1 | | 5.0 | 5.2 | | 1.8 | 2.6 | | 4.4 | 4.7 | |
| | | 64 | 37.08 | 3.1 | | | 5.2 | | | 2.3 | | | 4.4 | | | 1.8 | | | 3.9 | | |
| 22 | 3 | 16 | 10.65 | 3.3 | 6.0 | 7.9 | 7.1 | 10.3 | 12.5 | 2.5 | 5.2 | 7.0 | 6.4 | 9.5 | 11.8 | 2.0 | 4.7 | 6.5 | 5.9 | 9.1 | 11.3 |
| | | 24 | 14.05 | 3.1 | 4.9 | 5.9 | 7.3 | 9.4 | 10.8 | 2.3 | 4.1 | 5.0 | 6.5 | 8.7 | 10.0 | 1.9 | 3.6 | 4.5 | 6.1 | 8.2 | 9.5 |
| | | 32 | 16.45 | 3.3 | 4.3 | 5.3 | 7.7 | 9.1 | 10.5 | 2.5 | 3.4 | 4.3 | 7.0 | 8.3 | 9.7 | 2.0 | 2.8 | 3.8 | 6.5 | 7.8 | 9.2 |
| | | 40 | 17.74 | 3.5 | 4.5 | 4.5 | 8.3 | 9.7 | 10.1 | 2.6 | 3.5 | 3.5 | 7.5 | 8.9 | 9.3 | 2.0 | 3.0 | 2.9 | 7.0 | 8.4 | 8.7 |
| | | 48 | 19.18 | 3.9 | 3.7 | 4.1 | 8.9 | 9.3 | 10.2 | 2.7 | 2.7 | 3.2 | 8.0 | 8.4 | 9.3 | 2.2 | 2.1 | 2.4 | 7.5 | 7.9 | 8.8 |
| | | 56 | 18.66 | 4.0 | 4.4 | | 9.6 | 10.5 | | 3.0 | 3.3 | | 8.7 | 9.6 | | 2.4 | 2.7 | | 8.2 | 9.1 | |
| | | 64 | 19.08 | 4.1 | | | 10.2 | | | 3.1 | | | 9.4 | | | 2.5 | | | 8.8 | | |
| 24 | 1 | 16 | 33.89 | 2.0 | 4.7 | 6.5 | | | | 1.4 | 4.1 | 5.9 | | | | 1.0 | 3.7 | 5.5 | | | |
| | | 24 | 43.98 | 2.0 | 3.8 | 4.9 | | | | 1.4 | 3.1 | 4.3 | | | | 1.0 | 2.8 | 3.9 | | | |
| | | 32 | 51.95 | 2.1 | 3.2 | 4.1 | | | | 1.4 | 2.5 | 3.4 | | | | 1.1 | 2.2 | 3.1 | | | |
| | | 40 | 56.95 | 2.2 | 3.1 | 3.3 | | | | 1.6 | 2.5 | 2.6 | | | | 1.2 | 2.1 | 2.1 | | | |
| | | 48 | 62.25 | 2.2 | 2.4 | 2.7 | | | | 1.6 | 1.7 | 2.0 | | | | 1.2 | 1.3 | 1.7 | | | |
| | | 56 | 61.85 | 2.4 | 2.7 | | | | | 1.7 | 2.0 | | | | | 1.3 | 1.6 | | | | |
| | | 64 | 63.61 | 2.3 | | | | | | 1.7 | | | | | | 1.3 | | | | | |
| 24 | 2 | 16 | 21.74 | 2.1 | 3.1 | 3.3 | 6.6 | 9.4 | 11.3 | 1.5 | 4.5 | 6.6 | 6.0 | 8.8 | 10.7 | 1.1 | 4.0 | 6.2 | 5.6 | 8.3 | 10.3 |
| | | 24 | 29.10 | 2.0 | 4.2 | 5.7 | 6.3 | 8.1 | 9.3 | 1.5 | 3.5 | 5.1 | 5.7 | 7.5 | 8.7 | 1.1 | 3.2 | 4.7 | 5.3 | 7.7 | 8.3 |
| | | 32 | 35.03 | 2.1 | 3.6 | 4.9 | 6.0 | 7.2 | 8.1 | 1.5 | 3.0 | 4.3 | 5.3 | 6.5 | 7.4 | 1.1 | 2.6 | 4.0 | 5.0 | 6.1 | 7.2 |
| | | 40 | 38.43 | 2.3 | 3.6 | 4.2 | 5.8 | 6.7 | 6.9 | 1.7 | 2.9 | 3.5 | 5.2 | 6.1 | 6.2 | 1.3 | 2.5 | 3.1 | 4.8 | 5.7 | 5.9 |
| | | 48 | 46.15 | 2.3 | 2.8 | 3.6 | 5.3 | 5.5 | 5.8 | 1.6 | 2.1 | 2.9 | 4.7 | 4.8 | 5.1 | 1.2 | 1.7 | 2.7 | 4.3 | 4.5 | 4.6 |
| | | 56 | 48.02 | 2.4 | 3.2 | | 5.1 | 5.4 | | 1.7 | 2.5 | | 4.4 | 4.7 | | 1.3 | 2.1 | | 4.0 | 4.2 | |
| | | 64 | 50.50 | 2.4 | | | 4.5 | | | 1.7 | | | 3.8 | | | 1.3 | | | 3.4 | | |
| 24 | 3 | 16 | 13.14 | 3.3 | 5.0 | 7.0 | 6.8 | 8.9 | 11.2 | 1.7 | 4.4 | 6.2 | 5.3 | 8.4 | 10.5 | 1.1 | 3.9 | 5.7 | 5.8 | 8.2 | 10.2 |
| | | 24 | 18.41 | 3.3 | 4.2 | 5.4 | 6.1 | 7.5 | 9.0 | 1.7 | 3.5 | 4.5 | 5.2 | 6.6 | 7.7 | 1.1 | 3.0 | 4.1 | 5.8 | 7.2 | 8.1 |
| | | 32 | 23.16 | 3.4 | 3.9 | 4.6 | 6.0 | 6.7 | 7.4 | 1.7 | 2.9 | 3.8 | 5.1 | 5.7 | 6.4 | 1.1 | 2.4 | 3.4 | 5.7 | 6.3 | 7.0 |
| | | 40 | 27.26 | 3.4 | 3.5 | 3.9 | 5.8 | 6.3 | 6.5 | 1.9 | 2.9 | 3.2 | 5.0 | 5.4 | 5.6 | 1.3 | 2.4 | 2.9 | 5.6 | 6.0 | 6.2 |
| | | 48 | 29.87 | 3.5 | 3.3 | 3.7 | 5.6 | 5.9 | 6.1 | 1.9 | 2.7 | 3.0 | 4.8 | 5.1 | 5.3 | 1.4 | 2.2 | 2.7 | 5.4 | 5.7 | 5.9 |
| | | 56 | 30.41 | 3.6 | 3.7 | | 5.5 | 5.8 | | 2.0 | 2.8 | | 4.7 | 5.0 | | 1.4 | 2.3 | | 5.3 | 5.6 | |
| | | 64 | 31.76 | 3.7 | | | 5.4 | | | 2.0 | | | 4.6 | | | 1.4 | | | 5.2 | | |
| 26 | 1 | 16 | 4.61 | 3.1 | 4.1 | 5.1 | | | | 1.1 | 3.0 | 3.8 | | | | 1.3 | 3.7 | 4.6 | | | |
| | | 24 | 6.11 | 3.2 | 3.9 | 4.6 | | | | 1.2 | 2.7 | 3.5 | | | | 1.2 | 3.3 | 4.1 | | | |
| | | 32 | 7.31 | 3.3 | 3.8 | 4.3 | | | | 1.3 | 2.6 | 3.3 | | | | 1.2 | 3.2 | 3.9 | | | |
| | | 40 | 8.41 | 3.4 | 3.7 | 4.0 | | | | 1.3 | 2.5 | 3.1 | | | | 1.2 | 3.1 | 3.7 | | | |
| | | 48 | 9.41 | 3.5 | 3.6 | 3.8 | | | | 1.4 | 2.4 | 2.9 | | | | 1.3 | 3.0 | 3.5 | | | |
| | | 56 | 9.51 | 3.6 | 3.8 | | | | | 1.4 | 2.6 | | | | | 1.3 | 3.2 | | | | |
| | | 64 | 9.61 | 3.7 | | | | | | 1.4 | | | | | | 1.3 | | | | | |
| 26 | 2 | 16 | 3.61 | 3.0 | 3.9 | 4.8 | | | | 1.0 | 2.8 | 3.6 | | | | 1.2 | 3.5 | 4.4 | | | |
| | | 24 | 4.81 | 3.1 | 3.7 | 4.4 | | | | 1.1 | 2.6 | 3.3 | | | | 1.1 | 3.2 | 3.9 | | | |
| | | 32 | 5.81 | 3.2 | 3.6 | 4.1 | | | | 1.2 | 2.5 | 3.1 | | | | 1.1 | 3.1 | 3.7 | | | |
| | | 40 | 6.71 | 3.3 | 3.5 | 3.8 | | | | 1.2 | 2.4 | 2.9 | | | | 1.2 | 3.0 | 3.5 | | | |
| | | 48 | 7.51 | 3.4 | 3.4 | 3.6 | | | | 1.3 | 2.3 | 2.7 | | | | 1.2 | 2.9 | 3.3 | | | |
| | | 56 | 7.61 | 3.5 | 3.6 | | | | | 1.3 | 2.5 | | | | | 1.2 | 3.1 | | | | |
| | | 64 | 7.71 | 3.6 | | | | | | 1.3 | | | | | | 1.2 | | | | | |
| 26 | 3 | 16 | 2.91 | 2.9 | 3.8 | 4.7 | | | | 1.0 | 2.7 | 3.5 | | | | 1.1 | 3.4 | 4.3 | | | |
| | | 24 | 3.91 | 3.0 | 3.6 | 4.3 | | | | 1.0 | 2.5 | 3.2 | | | | 1.1 | 3.1 | 3.8 | | | |
| | | 32 | 4.71 | 3.1 | 3.5 | 4.0 | | | | 1.1 | 2.4 | 3.0 | | | | 1.1 | 3.0 | 3.6 | | | |
| | | 40 | 5.41 | 3.2 | 3.4 | 3.7 | | | | 1.2 | 2.3 | 2.8 | | | | 1.1 | 2.9 | 3.4 | | | |
| | | 48 | 6.01 | 3.3 | 3.3 | 3.5 | | | | 1.2 | 2.2 | 2.6 | | | | 1.1 | 2.8 | 3.2 | | | |
| | | 56 | 6.11 | 3.4 | 3.5 | | | | | 1.2 | 2.4 | | | | | 1.1 | 3.0 | | | | |
| | | 64 | 6.21 | 3.5 | | | | | | 1.2 | | | | | | 1.1 | | | | | |

Table 9.—Continued

| D.b.h. inches | Butt log grade | Merchantable height feet | Initial value dollars | Vigor I | | | | | | Vigor II | | | | | | Vigor III | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No change in butt log grade with height increase feet of | | | Increase in butt log grade with height increase feet of | | | No change in butt log grade with height increase feet of | | | Increase in butt log grade with height increase feet of | | | No change in butt log grade with height increase feet of | | | Increase in butt log grade with height increase feet of | | |
| | | | | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 |
| 26 | 3 | 16 | 19.72 | 1.9 | 4.8 | 6.8 | 5.2 | 8.5 | 10.8 | 1.3 | 4.2 | 6.1 | 4.7 | 7.9 | 10.1 | 1.1 | 3.9 | 5.9 | 4.5 | 7.7 | 9.9 |
| | | 24 | 25.73 | 2.0 | 4.9 | 7.3 | 5.6 | 7.9 | 8.9 | 1.5 | 3.4 | 4.6 | 5.1 | 7.3 | 8.9 | 1.2 | 3.1 | 4.3 | 4.8 | 7.0 | 8.6 |
| | | 32 | 30.90 | 2.1 | 3.4 | 4.3 | 5.9 | 7.5 | 8.7 | 1.5 | 2.7 | 3.7 | 5.3 | 6.9 | 8.2 | 1.2 | 2.4 | 3.4 | 5.1 | 6.6 | 7.9 |
| | | 40 | 34.91 | 2.1 | 3.0 | 3.7 | 6.2 | 7.4 | 8.2 | 1.5 | 2.4 | 2.8 | 5.6 | 6.8 | 7.6 | 1.2 | 2.1 | 2.5 | 5.3 | 6.6 | 7.3 |
| | | 48 | 38.42 | 2.0 | 2.5 | 2.9 | 6.4 | 7.1 | 7.9 | 1.4 | 1.8 | 2.2 | 5.8 | 6.5 | 7.3 | 1.2 | 1.5 | 2.0 | 5.6 | 6.5 | 7.1 |
| | | 56 | 39.46 | 2.2 | 2.6 | | 6.9 | 7.6 | | 1.5 | 2.0 | — | 6.2 | 7.0 | | 1.3 | 1.7 | | 6.0 | 6.8 | |
| | | 64 | 41.18 | 2.2 | — | | 7.2 | | | 1.5 | | | 6.6 | | | 1.3 | | | 6.3 | | |
| 28 | 1 | 16 | 62.12 | 1.4 | 4.5 | 6.4 | | | | .9 | 4.1 | 5.9 | | | | .7 | 3.5 | 5.6 | | | |
| | | 24 | 69.13 | 1.6 | 3.4 | 4.7 | | | | 1.1 | 2.9 | 4.2 | | | | .9 | 2.7 | 3.9 | | | |
| | | 32 | 82.88 | 1.6 | 2.8 | 3.5 | | | | 1.1 | 2.3 | 3.0 | | | | .9 | 2.1 | 2.8 | | | |
| | | 40 | 93.16 | 1.6 | 2.3 | 2.8 | | | | 1.1 | 1.8 | 2.3 | | | | .9 | 1.6 | 2.0 | | | |
| | | 48 | 100.48 | 1.5 | 2.0 | 2.3 | | | | 1.0 | 1.5 | 1.8 | | | | .8 | 1.3 | 1.5 | | | |
| | | 56 | 103.93 | 1.7 | 1.9 | | | | | 1.2 | 1.4 | | | | | .9 | 1.3 | | | | |
| | | 64 | 107.19 | 1.6 | | | | | | 1.1 | | | | | | .9 | | | | | |
| 28 | 2 | 16 | 34.01 | 1.4 | 4.9 | 7.0 | 5.8 | 9.1 | 11.1 | 1.0 | 4.3 | 6.5 | 5.3 | 8.6 | 10.5 | .8 | 4.1 | 6.3 | 5.1 | 8.3 | 10.2 |
| | | 24 | 46.39 | 1.7 | 3.8 | 5.4 | 5.8 | 7.7 | 9.0 | 1.2 | 3.2 | 4.8 | 5.2 | 7.1 | 8.4 | .9 | 3.0 | 4.6 | 5.0 | 6.9 | 8.2 |
| | | 32 | 55.31 | 1.6 | 3.2 | 4.2 | 5.4 | 6.7 | 7.4 | 1.1 | 2.6 | 3.7 | 4.9 | 6.1 | 6.9 | .9 | 2.4 | 3.5 | 4.7 | 5.9 | 6.7 |
| | | 40 | 66.57 | 1.6 | 2.7 | 3.6 | 5.1 | 5.8 | 6.3 | 1.1 | 2.2 | 3.0 | 4.5 | 5.3 | 5.8 | .9 | 2.0 | 2.8 | 4.3 | 5.1 | 5.5 |
| | | 48 | 74.43 | 1.5 | 2.4 | 3.1 | 4.6 | 5.1 | 5.4 | 1.0 | 1.9 | 2.6 | 4.1 | 4.6 | 4.9 | .8 | 1.6 | 2.4 | 3.9 | 4.3 | 4.6 |
| | | 56 | 80.10 | 1.7 | 2.3 | | 4.4 | 4.6 | | 1.1 | 1.8 | | 3.8 | 4.1 | | .9 | 1.6 | | 3.6 | 3.9 | |
| | | 64 | 86.31 | 1.6 | | | 3.9 | | | 1.1 | | | 3.3 | | | .9 | | | 3.1 | | |
| 28 | 3 | 16 | 24.69 | 1.5 | 4.8 | 6.7 | 4.7 | 8.3 | 10.5 | 1.0 | 4.2 | 6.1 | 4.3 | 7.7 | 10.0 | .8 | 4.0 | 5.9 | 4.1 | 7.5 | 9.7 |
| | | 24 | 33.00 | 1.8 | 3.7 | 5.0 | 5.2 | 7.4 | 9.0 | 1.2 | 3.1 | 4.4 | 4.7 | 6.8 | 8.4 | 1.0 | 2.9 | 4.2 | 4.4 | 6.6 | 8.2 |
| | | 32 | 39.88 | 1.7 | 3.1 | 3.9 | 5.4 | 7.0 | 8.1 | 1.2 | 2.5 | 3.3 | 4.8 | 6.4 | 7.5 | .9 | 2.2 | 3.1 | 4.6 | 6.2 | 7.3 |
| | | 40 | 45.24 | 1.8 | 2.6 | 3.2 | 5.6 | 6.7 | 7.6 | 1.2 | 2.0 | 2.6 | 5.1 | 6.2 | 7.1 | 1.0 | 1.8 | 2.4 | 4.8 | 6.0 | 6.8 |
| | | 48 | 49.29 | 1.7 | 2.3 | 2.7 | 5.8 | 6.7 | 7.4 | 1.2 | 1.7 | 2.1 | 5.3 | 6.2 | 6.9 | .9 | 1.5 | 1.9 | 5.1 | 5.9 | 6.7 |
| | | 56 | 51.58 | 1.9 | 2.3 | | 6.2 | 6.9 | | 1.3 | 1.7 | | 5.7 | 6.4 | — | 1.0 | 1.4 | | 5.4 | 6.2 | |
| | | 64 | 53.91 | 1.8 | | | 6.5 | | | 1.2 | | | 5.9 | | | 1.0 | | | 5.7 | | |
| 30 | 1 | 16 | 62.64 | 1.2 | 4.5 | 6.4 | | | | .8 | 4.0 | 5.9 | | | | .7 | 4.0 | 5.8 | | | |
| | | 24 | 85.35 | 1.4 | 3.2 | 4.5 | | | | .9 | 2.7 | 4.0 | | | | .8 | 2.6 | 3.9 | | | |
| | | 32 | 102.04 | 1.4 | 2.6 | 3.3 | | | | .9 | 2.1 | 2.8 | | | | .8 | 2.0 | 2.7 | | | |
| | | 40 | 115.32 | 1.4 | 2.0 | 2.7 | | | | .9 | 1.5 | 2.2 | | | | .8 | 1.4 | 2.0 | | | |
| | | 48 | 122.93 | 1.4 | 2.0 | 2.4 | | | | .9 | 1.5 | 1.8 | | | | .8 | 1.4 | 1.7 | | | |
| | | 56 | 129.95 | 1.5 | 1.8 | | | | | .9 | 1.3 | | | | | .8 | 1.2 | | | | |
| | | 64 | 133.23 | 1.6 | | | | | | 1.0 | | | | | | .9 | | | | | |
| 30 | 2 | 16 | 41.09 | 1.3 | 4.8 | 7.0 | 5.6 | 9.0 | 11.0 | .8 | 4.3 | 6.5 | 5.2 | 8.5 | 10.5 | .7 | 4.3 | 6.4 | 5.1 | 8.4 | 10.4 |
| | | 24 | 57.48 | 1.4 | 3.5 | 5.1 | 5.4 | 7.3 | 8.7 | .9 | 3.0 | 4.6 | 5.0 | 6.8 | 8.2 | .8 | 2.9 | 4.5 | 4.9 | 6.7 | 8.1 |
| | | 32 | 70.73 | 1.4 | 3.0 | 3.9 | 5.2 | 6.5 | 7.1 | .9 | 2.5 | 3.4 | 4.7 | 6.0 | 6.6 | .8 | 2.4 | 3.3 | 4.6 | 5.8 | 6.5 |
| | | 40 | 82.44 | 1.4 | 2.4 | 3.4 | 4.9 | 5.5 | 6.2 | .9 | 1.9 | 2.9 | 4.3 | 5.0 | 5.6 | .8 | 1.8 | 3.6 | 4.2 | 4.9 | 5.5 |
| | | 48 | 90.91 | 1.4 | 2.4 | 3.1 | 4.5 | 5.2 | 5.5 | .9 | 1.9 | 2.6 | 4.0 | 4.6 | 5.0 | .8 | 1.8 | 2.5 | 3.9 | 4.5 | 4.8 |
| | | 56 | 99.71 | 1.5 | 2.2 | | 4.2 | 4.6 | | .9 | 1.6 | | 3.7 | 4.0 | | .8 | 1.5 | | 3.5 | 3.9 | |
| | | 64 | 106.46 | 1.5 | | | 3.9 | | | 1.0 | | | 3.3 | | | .9 | | | 3.2 | | |
| 30 | 3 | 16 | 30.27 | 1.4 | 4.8 | 6.7 | 4.4 | 8.1 | 10.4 | .9 | 4.2 | 6.2 | 4.0 | 7.6 | 9.8 | .8 | 4.1 | 6.1 | 3.9 | 7.5 | 9.7 |
| | | 24 | 41.56 | 1.5 | 3.4 | 4.8 | 4.7 | 6.9 | 8.6 | 1.0 | 2.9 | 4.3 | 4.2 | 6.4 | 8.1 | .9 | 2.8 | 4.1 | 4.1 | 6.3 | 7.9 |
| | | 32 | 50.13 | 1.5 | 2.9 | 3.6 | 4.9 | 6.6 | 7.6 | 1.0 | 2.3 | 3.1 | 4.4 | 6.1 | 7.1 | .9 | 2.2 | 2.9 | 4.3 | 5.9 | 6.9 |
| | | 40 | 57.19 | 1.5 | 2.3 | 3.1 | 5.2 | 6.2 | 7.3 | 1.0 | 1.7 | 2.5 | 4.7 | 5.7 | 6.7 | .9 | 1.6 | 2.4 | 4.6 | 5.5 | 6.6 |
| | | 48 | 61.62 | 1.5 | 2.3 | 2.8 | 5.4 | 6.5 | 7.2 | 1.0 | 1.7 | 2.2 | 4.9 | 5.9 | 6.7 | .9 | 1.6 | 2.1 | 4.8 | 5.8 | 6.5 |
| | | 56 | 65.93 | 1.6 | 2.1 | | 5.7 | 6.5 | | 1.0 | 1.5 | | 5.2 | 5.9 | | .9 | 1.4 | | 5.1 | 5.8 | |
| | | 64 | 68.51 | 1.7 | | | 6.1 | | | 1.1 | | | 5.5 | | | 1.0 | | | 5.4 | | |

* Over 50 percent

Table 10.—Ten-year value increase for sugar maple, in dollars

| D.b.h. (inches) | Butt-log grade | Merchantable height (feet) | Initial value (dollars) | Vigor I | | | | | | Vigor II | | | | | | Vigor III | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No change in butt-log grade with height increase (feet) of— | | | Increase in butt-log grade with height increase (feet) of— | | | No change in butt-log grade with height increase (feet) of— | | | Increase in butt-log grade with height increase (feet) of— | | | No change in butt-log grade with height increase (feet) of— | | | Increase in butt-log grade with height increase (feet) of— | | |
| | | | | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 | 0 | 8 | 16 |
| 12 | 2 | 16 | 1.44 | 1.52 | 2.59 | 3.40 | 4.14 | 6.10 | 7.17 | 0.98 | 1.89 | 2.57 | 3.44 | 4.99 | 5.91 | 0.65 | 1.36 | 1.94 | 2.89 | 4.13 | 4.93 |
| | | 24 | 1.78 | 2.25 | 3.06 | | 5.76 | 6.83 | | 1.55 | 2.23 | | 4.65 | 5.57 | | 1.02 | 1.60 | | 3.79 | 4.59 | |
| | | 32 | | | | | | | | | | | | | | | | | | | |
| 12 | 3 | 16 | .21 | .91 | 1.11 | 1.03 | 2.65 | 3.82 | 4.63 | .62 | .70 | .55 | 2.22 | 3.12 | 3.80 | .42 | .40 | .21 | 1.88 | 2.60 | 3.17 |
| | | 24 | .04 | 1.27 | 1.20 | | 3.98 | 4.79 | | .86 | .71 | | 3.28 | 3.96 | | .57 | .37 | | 2.76 | 3.33 | |
| | | 32 | | | | | | | | | | | | | | | | | | | |
| 12 | 4 | 16 | .00 | .03 | .04 | .06 | 1.11 | 1.32 | 1.24 | .00 | .00 | .00 | .83 | .90 | .76 | .00 | .00 | .00 | .62 | .61 | .42 |
| | | 24 | .00 | .04 | .06 | | 1.32 | 1.24 | | .00 | .00 | .00 | .90 | .76 | | .00 | .00 | .00 | .61 | .42 | |
| | | 32 | | | | | | | | | | | | | | | | | | | |
| 14 | 2 | 16 | 2.56 | 2.16 | 4.00 | 5.49 | 6.01 | 8.89 | 10.83 | 1.55 | 3.17 | 4.50 | 5.04 | 7.61 | 9.37 | 1.02 | 2.47 | 3.57 | 4.19 | 6.55 | 7.99 |
| | | 24 | 3.57 | 3.00 | 4.49 | 5.39 | 7.89 | 9.83 | 10.51 | 2.17 | 3.50 | 4.26 | 6.61 | 8.37 | 8.92 | 1.47 | 2.57 | | 5.55 | 6.98 | |
| | | 32 | 4.26 | 3.79 | 4.69 | | 9.13 | 9.81 | | 2.80 | 3.57 | | 7.67 | 8.23 | | 1.87 | | | 6.29 | | |
| | | 40 | | | | | | | | | | | | | | | | | | | |
| 14 | 3 | 16 | .92 | 1.42 | 2.04 | 2.32 | 3.80 | 5.65 | 7.13 | 1.01 | 1.50 | 1.68 | 3.19 | 4.82 | 3.19 | .66 | 1.04 | 1.10 | 2.66 | 4.12 | 5.21 |
| | | 24 | 1.04 | 1.92 | 2.20 | 2.07 | 5.53 | 7.02 | 7.92 | 1.38 | 1.56 | 1.37 | 4.70 | 6.02 | 6.79 | .92 | .99 | | 4.00 | 5.09 | |
| | | 32 | .91 | 2.33 | 2.20 | | 7.15 | 8.05 | | 1.69 | 1.50 | | 6.15 | 6.93 | | 1.12 | | | 5.23 | | |
| | | 40 | | | | | | | | | | | | | | | | | | | |
| 14 | 4 | 16 | .00 | .43 | .63 | .82 | 2.34 | 2.96 | 3.24 | .30 | .44 | .57 | 1.93 | 2.42 | 2.60 | .18 | .27 | .35 | 1.58 | 1.96 | 2.02 |
| | | 24 | .00 | .63 | .82 | .97 | 2.96 | 3.24 | 3.11 | .44 | .57 | .68 | 2.42 | 2.60 | 2.41 | .27 | .35 | | 1.96 | 2.02 | |
| | | 32 | .00 | .82 | .97 | | 3.24 | 3.11 | | .57 | .68 | | 2.60 | 2.41 | | .35 | | | 2.02 | | |
| | | 40 | | | | | | | | | | | | | | | | | | | |
| 16 | 1 | 16 | 8.20 | 4.68 | 9.02 | 11.68 | | | | 3.51 | 7.30 | 9.75 | | | | 2.40 | 5.83 | 7.91 | | | |
| | | 24 | 10.89 | 6.33 | 8.98 | 10.40 | | | | 4.61 | 7.06 | 8.31 | | | | 3.14 | 5.22 | 9.02 | | | |
| | | 32 | 12.81 | 7.06 | 8.47 | 9.39 | | | | 5.13 | 6.39 | 7.50 | | | | 3.30 | 4.01 | | | | |
| | | 40 | 13.43 | 7.85 | 8.97 | | | | | 5.77 | 6.87 | | | | | 3.79 | | | | | |
| | | 48 | | | | | | | | | | | | | | | | | | | |
| 16 | 2 | 16 | 4.48 | 3.00 | 5.92 | 8.06 | 8.39 | 12.73 | 15.39 | 2.24 | 4.77 | 6.72 | 7.23 | 11.02 | 13.47 | 1.52 | 3.78 | 5.43 | 6.12 | 9.55 | 11.63 |
| | | 24 | 6.20 | 4.20 | 6.34 | 7.93 | 11.01 | 13.67 | 15.08 | 3.05 | 5.00 | 8.44 | 9.80 | 11.75 | 13.00 | 2.06 | 3.73 | 6.72 | 7.83 | 9.91 | 12.74 |
| | | 32 | 7.06 | 4.88 | 6.47 | 8.12 | 12.22 | 13.63 | 14.75 | 3.54 | 4.97 | 6.53 | 10.29 | 11.55 | 12.65 | 2.28 | 3.55 | | 8.46 | 9.67 | |
| | | 40 | 8.50 | 5.63 | 7.28 | | 12.79 | 13.91 | | 4.13 | 5.89 | | 10.70 | 11.81 | | 2.70 | | | 8.72 | | |
| | | 48 | | | | | | | | | | | | | | | | | | | |
| 16 | 3 | 16 | 1.47 | 2.09 | 3.41 | 4.11 | 5.31 | 8.23 | 10.37 | 1.54 | 2.61 | 3.19 | 4.55 | 7.08 | 9.03 | 1.03 | 1.92 | 2.34 | 3.83 | 6.09 | 7.76 |
| | | 24 | 2.23 | 2.86 | 3.56 | 3.79 | 7.67 | 9.81 | 11.40 | 2.06 | 2.63 | 2.77 | 6.52 | 8.47 | 9.89 | 1.37 | 1.78 | 2.39 | 5.54 | 7.20 | 9.03 |
| | | 32 | 2.98 | 3.30 | 3.54 | 3.61 | 9.56 | 11.15 | 12.80 | 2.58 | 2.52 | 2.53 | 8.22 | 9.65 | 11.21 | 1.53 | 1.78 | | 6.96 | 8.22 | |
| | | 40 | 3.81 | 3.70 | 3.77 | | 11.31 | 12.96 | | 2.68 | 2.69 | | 9.81 | 11.37 | | 1.71 | | | 8.38 | | |
| | | 48 | | | | | | | | | | | | | | | | | | | |
| 18 | 1 | 16 | 12.69 | 7.77 | 11.83 | 15.71 | | | | 4.08 | 9.72 | 13.25 | | | | 2.96 | | | | | |
| | | 24 | 16.85 | 9.89 | 11.57 | 13.41 | | | | 5.58 | 9.11 | 10.96 | | | | 4.06 | 7.76 | | | | |
| | | 32 | 19.48 | 8.92 | 10.79 | 12.65 | | | | 6.46 | 8.31 | 9.85 | | | | 4.61 | 6.33 | | | | |
| | | 40 | 20.80 | 9.38 | 11.26 | 9.44 | | | | 6.90 | 8.44 | | | | | 4.96 | 6.33 | | | | |
| | | 48 | 21.61 | 10.15 | 8.33 | | | | | 7.32 | | | | | | 5.23 | | | | | |
| | | 56 | | | | | | | | | | | | | | | | | | | |
| 18 | 2 | 16 | 7.36 | 3.87 | 8.03 | 11.76 | 11.16 | 17.16 | 21.04 | 2.70 | 6.58 | 9.45 | 9.41 | 15.06 | 18.58 | 1.96 | | | 8.30 | | |
| | | 24 | 10.13 | 5.78 | 8.42 | 11.37 | 14.38 | 18.26 | 20.13 | 3.80 | 6.67 | 8.34 | 12.76 | 15.80 | 17.65 | 2.76 | 5.38 | | 10.23 | 13.96 | |
| | | 32 | 12.22 | 6.30 | 8.44 | 10.60 | 16.14 | 18.01 | 19.80 | 4.55 | 6.61 | 8.23 | 13.67 | 15.33 | 15.96 | 3.21 | 5.19 | | 11.83 | 13.29 | |
| | | 40 | 13.85 | 6.85 | 9.06 | 8.55 | 16.43 | 18.31 | 16.49 | 5.04 | 7.18 | | 13.95 | 13.19 | | 3.62 | 5.38 | | 12.01 | 13.18 | |
| | | 48 | 14.84 | 7.46 | 7.34 | | 16.68 | 14.86 | | 5.55 | | | 13.86 | | | 3.95 | | | 11.72 | | |
| | | 56 | | | | | | | | | | | | | | | | | | | |
| 18 | 3 | 16 | 4.47 | 3.84 | 5.04 | 6.41 | 7.44 | 11.23 | 14.39 | 1.98 | 3.97 | 5.14 | 5.89 | 9.27 | 12.64 | 1.42 | | | 5.15 | | |
| | | 24 | 5.43 | 3.80 | 5.15 | 6.56 | 9.99 | 13.16 | 15.30 | 2.58 | 3.91 | 4.44 | 8.33 | 11.11 | 13.18 | 1.96 | 2.97 | | 7.49 | 10.10 | |
| | | 32 | 6.18 | 4.42 | 5.68 | 6.44 | 12.41 | 14.67 | 15.08 | 3.22 | 3.75 | 4.13 | 10.72 | 12.79 | 13.63 | 2.29 | 3.64 | | 9.42 | 11.46 | |
| | | 40 | 6.84 | 3.58 | 5.81 | 5.46 | 11.39 | 13.85 | 12.90 | 3.63 | 3.90 | | 12.36 | 11.71 | | 2.52 | 3.78 | | 12.11 | 13.10 | |
| | | 48 | 7.31 | 3.96 | 4.54 | | 11.80 | 10.85 | | 3.85 | | | 11.63 | | | 2.71 | | | 13.01 | | |
| | | 56 | | | | | | | | | | | | | | | | | | | |

Table 10 -- Continued

| Dbh inches | Butt log grade | Merch height 6 inch top, 16 foot log | Initial cubic volume | Vigor I: No change in butt log grade with height increase of: 0 | 8 | 16 | Vigor I: Increase in butt log grade with height increase of: 0 | 8 | 16 | Vigor II: No change in butt log grade with height increase of: 0 | 8 | 16 | Vigor II: Increase in butt log grade with height increase of: 0 | 8 | 16 | Vigor III: No change in butt log grade with height increase of: 0 | 8 | 16 | Vigor III: Increase in butt log grade with height increase of: 0 | 8 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 1 | 16 | 18.46 | 6.68 | 14.64 | 20.19 | | | | 4.87 | 12.20 | 17.33 | | | | 5.34 | 10.33 | 14.18 | | | |
| | | 24 | 24.52 | 8.87 | 14.13 | 17.14 | | | | 6.14 | 11.27 | 13.76 | | | | 4.29 | 9.42 | 11.10 | | | |
| | | 32 | 28.40 | 10.25 | 13.26 | 16.42 | | | | 7.39 | 9.88 | 12.88 | | | | 5.23 | 7.39 | 10.12 | | | |
| | | 40 | 30.25 | 11.39 | 14.52 | 13.23 | | | | 8.00 | 11.01 | 9.40 | | | | 5.63 | 8.25 | 6.57 | | | |
| | | 48 | 32.75 | 12.74 | 11.27 | 12.16 | | | | 9.13 | 7.32 | 8.57 | | | | 6.51 | 4.59 | | | | |
| | | 56 | 30.35 | 13.17 | 13.97 | | | | | 9.34 | 10.09 | | | | | 6.31 | | | | | |
| | | 64 | | | | | | | | | | | | | | | | | | | |
| 20 | 2 | 16 | 11.18 | 4.35 | 10.25 | 14.77 | 13.96 | 21.97 | 27.47 | 5.30 | 8.51 | 12.69 | 12.14 | 13.48 | 24.61 | 2.26 | 7.29 | 11.13 | 10.62 | 17.61 | 22.46 |
| | | 24 | 15.4 | 6.01 | 10.15 | 13.75 | 17.70 | 23.25 | 26.26 | 4.29 | 8.47 | 11.23 | 17.26 | 20.59 | 22.87 | 3.08 | 6.01 | 9.47 | 14.39 | 18.24 | 20.61 |
| | | 32 | 18.56 | 7.38 | 10.78 | 14.84 | 20.09 | 23.16 | 26.35 | 5.30 | 8.07 | 11.57 | 17.24 | 19.71 | 22.32 | 3.74 | 6.86 | 9.46 | 15.67 | 17.84 | 17.45 |
| | | 40 | 20.71 | 8.44 | 12.18 | 17.90 | 20.96 | 24.17 | 27.39 | 5.93 | 9.43 | 9.87 | 17.37 | 20.38 | 18.96 | 4.16 | 7.30 | 7.63 | 15.28 | 17.81 | 16.13 |
| | | 48 | 23.17 | 9.73 | 10.44 | 13.49 | 21.72 | 24.34 | 21.14 | 6.96 | 7.41 | 10.01 | 18.12 | 16.51 | 17.25 | 4.85 | 5.17 | | 15.35 | 13.67 | |
| | | 56 | 23.21 | 10.39 | 13.14 | | 20.29 | 21.99 | | 7.36 | 9.96 | | 16.46 | 17.21 | | 5.13 | | | 13.63 | | |
| | | 64 | | | | | | | | | | | | | | | | | | | |
| 20 | 3 | 16 | 6.38 | 3.48 | 6.79 | 9.12 | 8.76 | 14.43 | 18.96 | 2.50 | 5.47 | 7.55 | 7.51 | 12.71 | 16.89 | 1.71 | 4.47 | 6.37 | 6.47 | 11.49 | 15.63 |
| | | 24 | 9.21 | 4.57 | 6.89 | 8.17 | 12.20 | 16.74 | 19.44 | 3.25 | 5.32 | 6.31 | 10.48 | 14.66 | 17.42 | 2.25 | 4.14 | 5.00 | 9.17 | 13.10 | 15.66 |
| | | 32 | 10.58 | 5.52 | 6.80 | 8.17 | 15.35 | 18.57 | 22.32 | 3.95 | 4.94 | 6.14 | 13.29 | 16.05 | 19.55 | 2.77 | 3.63 | 4.61 | 11.73 | 14.29 | 17.44 |
| | | 40 | 11.17 | 6.31 | 7.28 | 7.03 | 17.98 | 21.73 | 22.44 | 4.35 | 5.55 | 4.88 | 15.46 | 18.96 | 19.41 | 3.03 | 4.02 | 3.29 | 13.20 | 16.85 | 17.17 |
| | | 48 | 11.73 | 7.02 | 6.47 | 6.84 | 21.17 | 21.88 | 24.63 | 4.99 | 4.32 | 4.59 | 18.40 | 18.84 | 21.45 | 3.45 | 2.73 | | 16.29 | 16.61 | |
| | | 56 | 10.91 | 7.29 | 7.66 | | 22.69 | 25.44 | | 5.14 | 5.41 | | 19.67 | 22.26 | | 3.55 | | | 17.48 | | |
| | | 64 | | | | | | | | | | | | | | | | | | | |
| 22 | 1 | 16 | 25.52 | 7.58 | 17.35 | 23.04 | | | | 5.50 | 14.74 | 21.98 | | | | 4.36 | 13.27 | 20.09 | | | |
| | | 24 | 33.62 | 9.25 | 16.94 | 21.81 | | | | 6.65 | 13.88 | 17.83 | | | | 5.17 | 11.99 | 15.71 | | | |
| | | 32 | 39.30 | 11.26 | 16.13 | 21.21 | | | | 8.19 | 12.15 | 16.89 | | | | 6.31 | 10.03 | 14.45 | | | |
| | | 40 | 42.32 | 13.11 | 18.19 | 17.64 | | | | 9.13 | 13.88 | 13.25 | | | | 7.02 | 11.44 | 10.51 | | | |
| | | 48 | 45.65 | 14.86 | 14.31 | 16.03 | | | | 10.54 | 9.92 | 11.26 | | | | 8.10 | 7.18 | 8.57 | | | |
| | | 56 | 44.32 | 15.63 | 17.36 | | | | | 11.25 | 12.59 | | | | | 8.51 | 9.89 | | | | |
| | | 64 | 45.19 | 16.49 | | | | | | 11.72 | | | | | | 9.03 | | | | | |
| 22 | 2 | 16 | 15.99 | 5.20 | 12.33 | 18.58 | 17.11 | 26.88 | 34.57 | 3.78 | 10.50 | 16.37 | 15.03 | 24.27 | 31.51 | 3.00 | 9.47 | 15.02 | 13.88 | 22.80 | 29.62 |
| | | 24 | 21.78 | 6.54 | 12.79 | 17.58 | 21.09 | 28.78 | 33.65 | 4.72 | 10.38 | 14.66 | 18.49 | 25.72 | 29.67 | 3.68 | 9.23 | 13.10 | 17.91 | 23.83 | 27.55 |
| | | 32 | 26.42 | 8.15 | 12.94 | 18.39 | 24.15 | 29.01 | 34.09 | 5.95 | 10.02 | 15.13 | 21.08 | 25.63 | 29.77 | 4.59 | 8.46 | 13.28 | 19.19 | 22.91 | 27.33 |
| | | 40 | 29.63 | 9.72 | 13.17 | 16.91 | 25.80 | 30.87 | 30.33 | 6.80 | 11.91 | 13.49 | 21.81 | 26.56 | 25.94 | 5.26 | 10.07 | 11.86 | 19.70 | 24.12 | 23.29 |
| | | 48 | 33.48 | 11.33 | 13.06 | 17.01 | 27.03 | 26.48 | 28.20 | 8.07 | 9.64 | 13.17 | 22.71 | 22.09 | 23.43 | 6.23 | 7.51 | 10.99 | 20.27 | 19.35 | 20.74 |
| | | 56 | 34.25 | 12.29 | 16.24 | | 25.70 | 27.43 | | 8.87 | 12.39 | | 21.32 | 22.66 | | 6.74 | 10.22 | | 18.58 | 19.96 | |
| | | 64 | 37.08 | 13.41 | | | 24.69 | | | 9.57 | | | 19.83 | | | 7.39 | | | 17.14 | | |
| 22 | 3 | 16 | 10.65 | 4.05 | 8.49 | 12.05 | 10.54 | 17.67 | 23.92 | 2.94 | 7.07 | 10.36 | 9.12 | 15.84 | 21.71 | 2.33 | 6.27 | 9.33 | 8.33 | 14.81 | 20.36 |
| | | 24 | 14.05 | 5.08 | 8.65 | 10.99 | 14.27 | 20.52 | 25.31 | 3.67 | 6.96 | 8.82 | 12.44 | 18.31 | 22.39 | 2.87 | 5.93 | 7.67 | 11.40 | 16.96 | 20.83 |
| | | 32 | 16.45 | 6.24 | 8.59 | 11.07 | 18.12 | 22.91 | 28.36 | 4.55 | 6.42 | 8.69 | 15.91 | 19.99 | 25.10 | 3.53 | 5.27 | 7.34 | 14.56 | 18.43 | 23.25 |
| | | 40 | 17.74 | 7.29 | 9.78 | 9.76 | 21.61 | 27.06 | 28.80 | 5.13 | 7.40 | 7.30 | 18.69 | 23.81 | 25.38 | 3.97 | 6.05 | 5.80 | 17.14 | 21.96 | 23.25 |
| | | 48 | 19.18 | 8.35 | 8.33 | 9.39 | 25.63 | 27.37 | 31.31 | 5.96 | 5.86 | 7.68 | 22.37 | 23.95 | 27.47 | 4.62 | 4.36 | 5.16 | 20.53 | 21.81 | 25.29 |
| | | 56 | 18.66 | 8.48 | 9.91 | | 27.88 | 31.83 | | 6.38 | 7.20 | | 24.46 | 27.99 | | 4.88 | 5.68 | | 22.33 | 25.81 | |
| | | 64 | 19.08 | 9.49 | | | 31.41 | | | 6.78 | | | 27.37 | | | 5.26 | | | 25.39 | | |
| 24 | 1 | 16 | 33.89 | 7.34 | 19.48 | 29.78 | | | | 5.18 | 16.65 | 25.97 | | | | 3.70 | 14.70 | 24.10 | | | |
| | | 24 | 43.98 | 9.39 | 19.78 | 27.20 | | | | 6.56 | 15.88 | 22.92 | | | | 4.61 | 14.01 | 20.43 | | | |
| | | 32 | 51.96 | 11.71 | 19.13 | 25.56 | | | | 7.91 | 14.94 | 20.92 | | | | 6.03 | 12.45 | 18.21 | | | |
| | | 40 | 56.95 | 14.34 | 20.57 | 21.71 | | | | 9.96 | 15.93 | 16.56 | | | | 7.47 | 13.22 | 13.61 | | | |
| | | 48 | 62.25 | 15.27 | 16.41 | 18.77 | | | | 10.63 | 11.26 | 13.43 | | | | 7.92 | 8.31 | 10.33 | | | |
| | | 56 | 61.85 | 16.81 | 19.17 | | | | | 11.66 | 13.82 | | | | | 8.71 | 10.73 | | | | |
| | | 64 | 63.64 | 17.38 | | | | | | 12.04 | | | | | | 8.94 | | | | | |
| 24 | 2 | 16 | 21.74 | 4.97 | 13.86 | 22.12 | 19.49 | 31.63 | 41.93 | 3.51 | 11.92 | 19.45 | 17.33 | 28.80 | 38.12 | 2.52 | 10.58 | 18.12 | 15.85 | 26.85 | 36.25 |
| | | 24 | 29.10 | 6.50 | 14.76 | 21.64 | 24.27 | 34.57 | 41.99 | 4.56 | 12.09 | 18.62 | 21.44 | 30.76 | 37.80 | 3.22 | 11.76 | 16.81 | 19.49 | 28.89 | 35.31 |
| | | 32 | 35.57 | 8.30 | 15.17 | 21.95 | 28.10 | 35.52 | 41.95 | 5.62 | 12.15 | 18.51 | 24.29 | 31.33 | 37.31 | 4.29 | 10.34 | 16.49 | 22.42 | 28.84 | 34.60 |
| | | 40 | 40.48 | 10.26 | 17.04 | 20.47 | 30.61 | 37.04 | 38.18 | 7.24 | 13.60 | 16.53 | 26.43 | 32.40 | 33.03 | 5.44 | 11.58 | 14.26 | 23.94 | 29.69 | 30.08 |
| | | 48 | 46.13 | 11.40 | 14.82 | 19.74 | 31.39 | 32.54 | 34.89 | 7.96 | 10.88 | 15.53 | 26.76 | 27.39 | 29.55 | 5.94 | 8.62 | 11.18 | 24.04 | 24.43 | 26.45 |
| | | 56 | 48.02 | 12.93 | 17.85 | | 30.65 | 33.00 | | 8.99 | 13.64 | | 25.50 | 27.66 | | 6.73 | 11.19 | | 22.54 | 24.56 | |
| | | 64 | 52.07 | 13.80 | | | 28.95 | | | 9.59 | | | 23.61 | | | 7.13 | | | 20.51 | | |
| 24 | 3 | 16 | 15.13 | 3.86 | 9.62 | 14.61 | 11.57 | 20.47 | 28.73 | 2.73 | 8.12 | 12.60 | 10.12 | 18.53 | 26.06 | 1.97 | 7.11 | 11.59 | 9.12 | 17.19 | 24.73 |
| | | 24 | 19.74 | 5.01 | 10.00 | 13.74 | 15.86 | 24.12 | 31.00 | 3.51 | 7.99 | 11.50 | 13.91 | 21.45 | 27.98 | 2.50 | 6.98 | 10.16 | 12.58 | 20.12 | 26.17 |
| | | 32 | 23.46 | 6.28 | 10.02 | 13.38 | 20.41 | 24.28 | 34.06 | 4.28 | 7.78 | 10.87 | 17.73 | 24.26 | 30.62 | 3.26 | 6.44 | 9.39 | 16.40 | 22.45 | 28.60 |
| | | 40 | 25.88 | 7.60 | 10.96 | 11.90 | 24.86 | 31.64 | 35.07 | 5.36 | 8.45 | 9.10 | 21.84 | 28.20 | 31.13 | 4.02 | 6.97 | 7.48 | 20.03 | 26.18 | 28.86 |
| | | 48 | 28.50 | 8.34 | 9.28 | 10.89 | 29.02 | 32.45 | 37.37 | 5.83 | 6.48 | 7.94 | 25.58 | 28.51 | 33.16 | 4.35 | 4.86 | 6.22 | 23.56 | 26.24 | 30.70 |
| | | 56 | 28.56 | 9.22 | 10.83 | | 32.38 | 37.31 | | 6.42 | 7.87 | | 28.45 | 33.09 | | 4.80 | 6.15 | | 26.18 | 30.64 | |
| | | 64 | 29.69 | 9.70 | | | 36.18 | | | 6.75 | | | 31.97 | | | 5.03 | | | 29.51 | | |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 1 | 16 | 42 61 | 7.61 | 23.63 | 36.75 | — | — | — | 5 32 | 20 32 | 32 54 | — | — | — | 4.32 | 18.99 | 30 90 | — | — | — | | |
| | | 24 | 55 23 | 11.00 | 24.13 | 33.74 | — | — | — | 7.70 | 19 92 | 28 74 | — | — | — | 6.36 | 18.28 | 26 84 | — | — | — | | |
| | | 32 | 65 85 | 13 51 | 23.12 | 30.46 | — | — | — | 9 30 | 18 12 | 25 35 | — | — | — | 7 66 | 16.22 | 23 34 | — | — | — | | |
| | | 40 | 73 77 | 15 20 | 22 54 | 25 49 | — | — | — | 10 20 | 17 43 | 19.81 | — | — | — | 8.30 | 15.42 | 17.71 | — | — | — | | |
| | | 48 | 80 43 | 15.87 | 18 83 | 21 85 | — | — | — | 10.77 | 13 15 | 15.95 | — | — | — | 8 75 | 11 05 | 13.68 | — | — | — | | |
| | | 56 | 81 72 | 17 54 | 20.56 | — | — | — | — | 11 85 | 14 66 | — | — | — | — | 9 76 | 12 39 | — | — | — | — | | |
| | | 64 | 84 22 | 18 06 | — | — | — | — | — | 12 16 | — | — | — | — | — | 9.89 | — | — | — | — | — | | |
| 26 | 2 | 16 | 27 63 | 5 10 | 16 78 | 27 22 | 22 59 | 38 61 | 51 73 | 3 56 | 14.52 | 24 28 | 20.29 | 35 30 | 47.52 | 2 90 | 13.60 | 23 13 | 19.30 | 33.97 | 45.88 | | |
| | | 24 | 36 89 | 7.52 | 17 96 | 26.69 | 29 35 | 42.47 | 52.08 | 5 26 | 15 02 | 23 11 | 26 05 | 38 26 | 47 08 | 4 35 | 13.87 | 21 74 | 24.71 | 36.62 | 45.18 | | |
| | | 32 | 45 40 | 9 45 | 18 18 | 25.97 | 33 96 | 43 57 | 50 91 | 6 51 | 14 60 | 22 22 | 29 75 | 38 57 | 45 80 | 5 36 | 13 23 | 20 74 | 28 11 | 36 67 | 43 79 | | |
| | | 40 | 52 67 | 10 90 | 18 70 | 23 90 | 36 30 | 43.64 | 46 59 | 7 32 | 14.95 | 19 61 | 31 30 | 38 53 | 40 91 | 5 96 | 13 47 | 18 02 | 29 40 | 36 52 | 38 81 | | |
| | | 48 | 59 68 | 11 69 | 16 89 | 22 81 | 36 62 | 39 58 | 39.00 | 7 94 | 12 60 | 18 22 | 31 52 | 33 90 | 36 70 | 6 45 | 11 01 | 16 45 | 29 50 | 31 80 | 34.43 | | |
| | | 56 | 63 28 | 13 29 | 19 21 | — | 35 98 | 39.00 | — | 8 99 | 14 62 | — | 30 29 | 33 10 | — | 7.41 | 12.85 | — | 28 20 | 30.83 | — | | |
| | | 64 | 68 39 | 14 10 | — | — | 33 89 | — | — | 9 51 | — | — | 27 99 | — | — | 7 74 | — | — | 25.72 | — | — | | |
| 26 | 3 | 16 | 19 72 | 3 97 | 11 75 | 18.29 | 13 02 | 24 69 | 35 13 | 2 77 | 10 01 | 16 07 | 11 48 | 22 43 | 32 19 | 2 25 | 9 31 | 15 20 | 10 81 | 21 51 | 31 04 | | |
| | | 24 | 25 73 | 5 74 | 12 28 | 17 27 | 18 68 | 29 12 | 37 85 | 4 00 | 10 06 | 14 61 | 16 41 | 26 18 | 34 27 | 3 30 | 9 19 | 13 60 | 15.50 | 25.03 | 32 90 | | |
| | | 32 | 30 90 | 7 11 | 12.10 | 16 12 | 23 95 | 32 68 | 40 47 | 4 88 | 9 44 | 13 35 | 21 00 | 29 10 | 36 72 | 4 02 | 8 43 | 12 26 | 19 86 | 27 73 | 35 24 | | |
| | | 40 | 34.91 | 8 09 | 12 11 | 14 11 | 28 66 | 36 46 | 41 66 | 5 43 | 9 34 | 11 01 | 25 08 | 32 71 | 37 37 | 4 42 | 8 25 | 9 86 | 23 72 | 31 23 | 35 78 | | |
| | | 48 | 38 42 | 8 60 | 10 60 | 12 76 | 32 95 | 38 15 | 44 07 | 5 83 | 7 50 | 9 49 | 29 20 | 33 86 | 39 48 | 4 74 | 6 35 | 8 23 | 27 71 | 32 27 | 37 71 | | |
| | | 56 | 39 46 | 9 56 | 11 72 | — | 37 11 | 43 03 | — | 6 46 | 8 45 | — | 32 81 | 38 44 | — | 5 31 | 7.19 | — | 31.23 | 36.67 | — | | |
| | | 64 | 41 18 | 10 00 | — | — | 41 31 | — | — | 6 73 | — | — | 36 72 | — | — | 5 47 | — | — | 34.95 | — | — | | |
| 28 | 1 | 16 | 52 12 | 7 71 | 29 13 | 44 85 | — | — | — | 5 10 | 25 26 | 40 02 | — | — | — | 4 03 | 23 67 | 38 11 | — | — | — | | |
| | | 24 | 69 13 | 12 12 | 27 84 | 40 24 | — | — | — | 8 25 | 23 01 | 35 69 | — | — | — | 6 66 | 21 10 | 32 49 | — | — | — | | |
| | | 32 | 82 88 | 14 10 | 26 49 | 34 26 | — | — | — | 9 27 | 20 94 | 28 60 | — | — | — | 7 35 | 18 74 | 26 41 | — | — | — | | |
| | | 40 | 93 16 | 16 22 | 23 98 | 29 83 | — | — | — | 10 67 | 18 32 | 23 38 | — | — | — | 8 47 | 16 13 | 20 74 | — | — | — | | |
| | | 48 | 100 48 | 16 67 | 22 51 | 25 57 | — | — | — | 11 01 | 16 06 | 19 12 | — | — | — | 8 81 | 13 42 | 16 63 | — | — | — | | |
| | | 56 | 103 93 | 19 05 | 22 12 | — | — | — | — | 12 61 | 15 67 | — | — | — | — | 9 97 | 13 18 | — | — | — | — | | |
| | | 64 | 107 19 | 18 86 | — | — | — | — | — | 12 41 | — | — | — | — | — | 9 92 | — | — | — | — | — | | |
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| | | 24 | 46 39 | 8 29 | 20 78 | 31 80 | 34 86 | 50 58 | 62 98 | 5 64 | 17 41 | 27 83 | 30 99 | 45 75 | 57 43 | 4 55 | 16 07 | 26 25 | 29 40 | 43 84 | 55 23 | | |
| | | 32 | 57 31 | 9 86 | 20 88 | 29 35 | 39 66 | 52 06 | 59 83 | 6 49 | 16 91 | 25 21 | 34 83 | 46 51 | 54 17 | 5 15 | 15 33 | 23 60 | 32 92 | 44 31 | 51 98 | | |
| | | 40 | 66 57 | 11 61 | 20 09 | 27 90 | 42 80 | 50 57 | 56 42 | 7 64 | 15 95 | 23 05 | 37 25 | 44 91 | 49 97 | 6 07 | 14 34 | 21 06 | 35 05 | 42 72 | 47 33 | | |
| | | 48 | 74 43 | 12 23 | 20 04 | 26 48 | 42 71 | 48 56 | 51 62 | 8 08 | 15 19 | 21 50 | 37 05 | 42 11 | 45 17 | 6 47 | 13 20 | 19 57 | 34 86 | 39 47 | 42 68 | | |
| | | 56 | 80 10 | 14 36 | 20 81 | — | 42 89 | 45 95 | — | 9 52 | 15 83 | — | 36 44 | 39 50 | — | 7 52 | 13 90 | — | 33 80 | 37 01 | — | | |
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| 28 | 3 | 16 | 24 69 | 4 08 | 14 69 | 22 71 | 14 50 | 29 99 | 42 48 | 2 70 | 12 64 | 20 13 | 12 75 | 27 34 | 39 11 | 2 13 | 11 79 | 19 11 | 12 03 | 26 25 | 37 77 | | |
| | | 24 | 33 00 | 6 38 | 14 40 | 20 98 | 21 68 | 34 17 | 45 19 | 4 33 | 11 82 | 17 98 | 19 03 | 30 80 | 41 22 | 3 49 | 10 80 | 16 79 | 17 94 | 29 46 | 39 64 | | |
| | | 32 | 39 88 | 7 52 | 14 10 | 18 55 | 27 29 | 38 31 | 46 78 | 4 94 | 11 10 | 15 44 | 23 92 | 34 34 | 42 64 | 3 92 | 9 91 | 14 23 | 22 58 | 32 76 | 41 03 | | |
| | | 40 | 44 24 | 8 54 | 13 19 | 16 84 | 32 95 | 41 42 | 49 23 | 5 74 | 10 08 | 13 28 | 28 98 | 37 28 | 44 38 | 4 56 | 8 87 | 11 82 | 27 40 | 35 67 | 42 39 | | |
| | | 48 | 49 24 | 9 13 | 12 79 | 15 20 | 37 37 | 45 18 | 51 62 | 6 02 | 9 23 | 11 57 | 33 23 | 40 33 | 46 64 | 4 82 | 7 77 | 10 17 | 31 62 | 38 34 | 44 71 | | |
| | | 56 | 54 58 | 10 49 | 12 91 | — | 42 89 | 49 33 | — | 6 93 | 9 28 | — | 38 04 | 44 35 | — | 5 48 | 7 88 | — | 36 05 | 42 42 | — | | |
| | | 64 | 58 91 | 10 68 | — | — | 47 00 | — | — | 6 95 | — | — | 42 02 | — | — | 5 55 | — | — | 40 09 | — | — | | |
| 30 | 1 | 16 | 62 61 | 8 26 | 35 07 | 54 20 | — | — | — | 5 30 | 30 59 | 48 84 | — | — | — | 4 65 | 29 74 | 47 81 | — | — | — | | |
| | | 24 | 85 3 | 12 36 | 31 49 | 47 21 | — | — | — | 7 88 | 26 13 | 40 77 | — | — | — | 7 03 | 25 10 | 39 45 | — | — | — | | |
| | | 32 | 102 05 | 14 79 | 30 51 | 38 84 | — | — | — | 9 43 | 24 07 | 32 03 | — | — | — | 8 40 | 22 75 | 30 72 | — | — | — | | |
| | | 40 | 115 42 | 17 24 | 27 57 | 35 36 | — | — | — | 10 80 | 18 76 | 27 47 | — | — | — | 9 48 | 17 45 | 25 91 | — | — | — | | |
| | | 48 | 122 03 | 17 95 | 27 67 | 32 81 | — | — | — | 11 15 | 19 86 | 24 55 | — | — | — | 9 84 | 18 30 | 22 90 | — | — | — | | |
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| | | 16 | 41 39 | 5 46 | 24 85 | 40 00 | 24 82 | 46 62 | 65 75 | 3 57 | 21 80 | 36 24 | 26 85 | 52 14 | 70 39 | 3 13 | 21 21 | 35 62 | 26 20 | 51 29 | 69 36 | | |
| | | 24 | 58 48 | 8 45 | 33 61 | 51 36 | 40 23 | 59 36 | 77 08 | 5 41 | 19 85 | 32 69 | 35 | 54 00 | 68 64 | 4 82 | 19 13 | 31 75 | 31 90 | 52 97 | 67 42 | | |
| | | 32 | 70 3 | 10 36 | 34 05 | 43 35 | 46 11 | 61 83 | 70 16 | 6 60 | 19 44 | 28 31 | 40 | 53 39 | 63 35 | 5 88 | 18 50 | 27 38 | 39 72 | 54 01 | 67 04 | | |
| | | 40 | 81 33 | 12 34 | 31 62 | 36 98 | 46 12 | 58 45 | 68 14 | 7 73 | 16 63 | 26 92 | 43 68 | 51 61 | 60 35 | 6 78 | 15 67 | 25 17 | 42 86 | 56 43 | 68 29 | | |
| | | 48 | 89 55 | 13 56 | 28 80 | 34 84 | 49 08 | 59 67 | 64 85 | 8 11 | 15 47 | 26 31 | 43 17 | 51 85 | 56 37 | 7 21 | 17 78 | 25 50 | 41 86 | 54 82 | 64 92 | | |
| | | 56 | 92 11 | 14 20 | 24 14 | — | 49 82 | 56 93 | — | 9 65 | 15 27 | — | 43 08 | 47 57 | — | 8 48 | 16 50 | — | 41 52 | 46 17 | — | | |
| | | 64 | 106 16 | 14 39 | — | — | 49 28 | — | — | 11 02 | — | — | 44 02 | — | — | 9 74 | — | — | 39 47 | — | — | | |
| | | 16 | 32 | 4 43 | 17 91 | 28 86 | 26 29 | 36 82 | 46 82 | 2 82 | 15 40 | 24 94 | 14 89 | 32 62 | 47 06 | 2 48 | 14 05 | 24 89 | 13 95 | 32 03 | 46 31 | | |
| | | 24 | 44 46 | 6 66 | 25 | 37 91 | 41 46 | 52 23 | 63 | 4 01 | 13 63 | 21 57 | 21 35 | 35 57 | 48 61 | 3 75 | 13 10 | 20 80 | 30 74 | 53 48 | 4 76 | | |
| | | 32 | 58 | 5 61 | 16 43 | 21 43 | 30 56 | 44 63 | 55 15 | 5 09 | 12 95 | 17 66 | 27 83 | 40 04 | 48 04 | 4 53 | 12 25 | 16 91 | 26 48 | 50 10 | 1 98 | | |
| | | 40 | 73 48 | 9 46 | 14 25 | 18 52 | 37 06 | 46 86 | 58 05 | 5 89 | 10 66 | 15 88 | 32 98 | 41 88 | 52 1 | 5 47 | 9 88 | 14 02 | 32 04 | 46 92 | 54 09 | | |
| | | 48 | 85 | 9 55 | 11 | 17 4 | 41 44 | 53 | 67 | 6 17 | 13 45 | 14 88 | 38 4 | 47 | 56 | 5 44 | 8 29 | 13 96 | 36 43 | 46 | 4 9 | | |
| | | 56 | 95 49 | 10 48 | 11 84 | — | 45 28 | 56 | — | 7 34 | 10 | — | 43 35 | 51 | — | 6 28 | 9 65 | — | 38 39 | 45 | — | | |
| | | 64 | 97 | 10 | — | — | 45 | — | — | 7 89 | — | — | 48 47 | — | — | 6 | — | — | 4 | — | — | | |

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# Identifying REGIONAL OPPORTUNITIES for Accelerated Timber Management

by David A. Gansner
Joseph E. Barnard
Samuel F. Gingrich

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WARREN T. DOOLITTLE, DIRECTOR

## The Authors

DAVID A. GANSNER is leader of the Northeastern Forest Experiment Station's production economics research work unit at Upper Darby, Pennsylvania. He received his degree in forestry from the University of Missouri in 1958, a master's degree in agriculture economics from Ohio State University in 1968, and a master's degree in regional science from the University of Pennsylvania in 1970. He has been with the USDA Forest Service since 1958.

JOSEPH E. BARNARD, research forester, earned his bachelor's degree in forestry at The Pennsylvania State University in 1960. He joined the Northeastern Forest Experiment Station as a field crew member of the Forest Survey in 1960. He returned to The Pennsylvania State University in 1962 and received his master's degree in forest ecology in 1963. After serving in the U. S. Army and completing some additional course work in statistics and ecology at The Pennsylvania State University, he returned to the Experiment Station in 1965 and has been stationed since that time at Upper Darby, Pa. He is currently responsible for forest-survey data-processing and for survey-techniques research.

SAMUEL F. GINGRICH, principal mensurationist, is leader of the Northeastern Forest Experiment Station's timber management research work unit at Columbus, Ohio. He received his bachelor and master of science degrees at The Pennsylvania State University in 1950 and 1954, and was an instructor at The Pennsylvania State University from 1951 to 1957. He joined the Central States Forest Experiment Station in 1957 as a staff mensurationist. Since 1964 he has been a project leader for the Northeastern Forest Experiment Station, conducting research in the growth and yield of upland oak forests.

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# Identifying REGIONAL OPPORTUNITIES for Accelerated Timber Management

**Abstract**

Describes a procedure for identifying regional opportunities for accelerated timber management and demonstrates its application. Results provide a basis for rational choices among alternative management strategies and permit meaningful micro- and macro-evaluations of treatment response.

MUCH ATTENTION has focused recently on the question of future supplies of timber in the United States. Many leading forest policy makers agree that foreseeable demands for timber can be met at current price levels, but only if large investments are made in forest management. This concern has stimulated proposals to increase the amount of public funds and technical assistance available for promoting accelerated timber-management practices.

But, few guidelines exist for making optimal use of these funds and services at the local level. Sound strategies for program orientation cannot be developed until regional oportunities for accelerated management have been clearly defined. What are the opportunities for timber management in a particular region? This paper outlines an objective procedure for answering this question and demonstrates its application to a typical problem.

## THE APPROACH

The woodlands of any region exhibit virtually every stage of stand condition and development. There is a practical method for disaggregating this variable resource into well-defined units of area that are relevant for the selection, analysis, and evaluation of timber-management practices. It involves three basic steps:

1. Select stand criteria that are necessary for treatment decision-making.
2. Use forest-inventory plot records to differentiate regional management-opportunity

classes that are homogeneous in terms of the criteria selected in step 1.

3. Derive stand profiles representing the structure of forest stands in each management-opportunity class.

Results provide a framework for making rational choices among alternative management strategies and permit meaningful micro- and macro-evaluations of treatment response.

## AN APPLICATION

The procedure for identifying regional opportunities for accelerated timber management was applied to oak-hickory stands of the Ohio Hill Country (fig. 1).

### Decision-Making Criteria Were Selected

Information about four key criteria of stand condition are necessary for decisions regarding the silvicultural treatment of oak-hickory stands:

1. *The basal area of all live trees* provides a general measure of total stand stocking.

Figure 1.—The procedure was applied in the Hill Country of Ohio.

2. *The level of stocking with acceptable trees* provides a measure of stand area occupied by trees that are worth managing.[1] The formula for calculating this level of stocking is:[2]

$$S = -0.00507N + 0.01698\Sigma D + 0.00127\Sigma D^2$$

in which S = level of stocking with acceptable trees; N = number of acceptable trees, and D = diameters of acceptable trees.

3. *The average diameter of acceptable trees* indicates the timber size class of the manageable stand.

4. *Site index* provides a measure of the stand's productive potential and in conjunction with criterion 3 provides an indirect estimate of stand age.

These variables of stand condition formed the basis for stratifying the Hill Country's 2.3 million acres of oak-hickory forest into management-opportunity classes.

### Inventory Plot Records Were Screened to Identify Management-Opportunity Classes

Some 680 oak-hickory ground plots, measured in the Hill Country of Ohio at the time of the last comprehensive forest inventory (1968), provided data for defining management-opportunity classes. Each plot, representing about 3,360 acres of commercial forest land, was screened and sorted on the criteria of stand condition listed above.[3] Six total-basal-area classes, three stocking-level classes, two average-diameter classes and five site-index classes were recognized.

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[1]For this study we assumed that trees fitting the standard forest-survey definition of "growing stock" were acceptable. *(DeBald and McCay 1969).*

[2]See Gingrich *(1967)* for explanation of the development and use of this stocking formula.

[3]FINSYS—Forest Inventory System—a computer processing system, provided the vehicle for screening and sorting the ground-plot data. FINSYS was described in a series of research papers by R. W. Wilson and R. C. Peters in 1967: *The Northeastern Forest Inventory Data Processing System,* USDA Forest Serv. Res. Pap. NE-61 and NE-70 to 78.

The screening identified a gross set of 77 distinct opportunity classes (table 1). Several of these opportunity classes were immediately excluded from consideration. Those with less than 15 thousand acres were dropped because basic data on stand condition available for such small units of area are subject to large sampling error. Classes in the < 50 site-index category were also eliminated. Past research has shown that timber producing investments

Table 1.—*Acreage of oak-hickory forest in southeastern Ohio, by management-opportunity classes*

| Total basal area (sq. ft.) | Average d.b.h. of acceptable trees (inches) | Site index | | | | |
|---|---|---|---|---|---|---|
| | | < 50 | 50-59 | 60-69 | 70-79 | 80 + |
| | | ACCEPTABLE TREE STOCKING LEVEL <C[a] | | | | |
| <40 | <11.0 | 84,100 | (60,500) ① | (104,200) ② | (40,300) ③ | (26,900) ④ |
| | 11.0+ | 3,400 | 3,400 | 3,400 | — | — |
| 40-59 | <11.0 | 13,400 | (47,100) ⑤ | (74,000) ⑥ | (23,500) ⑦ | (30,300) ⑧ |
| | 11.0+ | 3,400 | — | — | — | — |
| 60-79 | <11.0 | 6,700 | 6,700 | (16,800) ⑨ | 10,100 | 3,400 |
| | 11.0+ | — | 3,400 | 3,400 | — | — |
| 80-99 | <11.0 | — | — | — | 6,700 | 3,400 |
| | 11.0+ | — | — | 6,700 | — | — |
| 100-119 | <11.0 | — | — | — | 3,400 | — |
| | 11.0+ | — | — | — | — | 3,400 |
| 120+ | <11.0 | — | — | — | — | — |
| | 11.0+ | — | — | — | — | — |
| | | ACCEPTABLE TREE STOCKING LEVEL C TO B[a] | | | | |
| <40 | <11.0 | 3,400 | 10,100 | (16,800) ⑩ | 13,400 | 6,700 |
| | 11.0+ | — | — | — | — | — |
| 40-59 | <11.0 | 40,300 | (47,100) ⑪ | (40,300) ⑫ | (50,400) ⑬ | (26,900) ⑭ |
| | 11.0+ | — | — | — | — | — |
| 60-79 | <11.0 | 50,400 | (67,200) ⑮ | (90,800) ⑯ | (50,400) ⑰ | (43,700) ⑱ |
| | 11.0+ | — | — | — | — | — |
| 80-99 | <11.0 | 13,400 | (30,300) ⑲ | (40,300) ⑳ | (30,300) ㉑ | (16,800) ㉒ |
| | 11.0+ | — | — | — | 3,400 | — |
| 100-119 | <11.0 | 3,400 | — | 13,400 | — | 3,400 |
| | 11.0+ | — | — | — | — | — |
| 120+ | <11.0 | — | — | 3,400 | — | — |
| | 11.0+ | — | — | — | — | — |
| | | ACCEPTABLE TREE STOCKING LEVEL B+[a] | | | | |
| <40 | <11.0 | — | — | — | — | — |
| | 11.0+ | — | — | — | — | — |
| 40-59 | <11.0 | — | 6,700 | 6,700 | — | 3,400 |
| | 11.0+ | — | — | — | — | — |
| 60-79 | <11.0 | 10,100 | (37,000) ㉓ | (43,700) ㉔ | (16,800) ㉕ | 10,100 |
| | 11.0+ | — | 3,400 | — | — | — |
| 80-99 | <11.0 | 53,800 | (107,600) ㉖ | (121,000) ㉗ | (87,400) ㉘ | (63,900) ㉙ |
| | 11.0+ | — | — | — | 13,400 | — |
| 100-119 | <11.0 | 26,900 | (53,800) ㉚ | (74,000) ㉛ | (67,200) ㉜ | (63,900) ㉝ |
| | 11.0+ | — | — | 3,400 | — | — |
| 120+ | <11.0 | 6,700 | 13,400 | (26,900) ㉞ | (37,000) ㉟ | (26,900) ㊱ |
| | 11.0+ | — | — | — | — | — |

[a]For definitions of B and C stocking levels, see Central States Forest Experiment Station and North Central Region 1962 Timber management guide for upland central hardwoods. USDA Forest Serv., Cent. States Forest Exp. Sta., 33 pp.

① Numbered items identify the 36 opportunity classes.

on these poorer sites generally yield very low returns. This left a net of 36 opportunity classes (numbered in table 1). They represent 1.8 million acres or four-fifths of the oak-hickory forest in the Hill Country.

## Stand Profiles Were Derived

The choice of specific management strategies and evaluation of their impact potential requires more detailed information about the structure of forest stands in each management-opportunity class. Stand-profile tables, depicting the representative (average) forest acre in each opportunity class, were developed from the forest-inventory plot records. These tables provide data on the number of trees, by species, d.b.h., and quality class. An example of one of these stand profiles (the one for opportunity class 6) is shown in table 2.

Table 2.—*Stand profile for management-opportunity class 6*

*Criteria of Stand Condition:*

| | |
|---|---|
| Total basal area | 49 |
| Stocking level | 26.8 |
| Average d.b.h. | 5.9 |
| Site index | 65 |

| D.b.h. (inches) | Species | Number of trees per acre | | |
|---|---|---|---|---|
| | | Acceptable | Cull | Total |
| 2 | A[a] | 10.9 | 5.5 | 16.4 |
| | B[b] | 15.0 | 6.8 | 21.8 |
| | C[c] | 44.9 | 145.9 | 190.8 |
| 4 | A | 1.4 | — | 1.4 |
| | B | 5.4 | 1.4 | 6.8 |
| | C | 20.4 | 38.2 | 58.6 |
| 6 | A | 2.1 | — | 2.1 |
| | B | .9 | 1.0 | 1.9 |
| | C | 11.8 | 18.7 | 30.5 |
| 8 | A | .9 | — | .9 |
| | B | 1.0 | — | 1.0 |
| | C | 9.1 | 4.1 | 13.2 |
| 10 | A | .6 | — | .6 |
| | B | 1.0 | — | 1.0 |
| | C | 7.1 | 4.0 | 11.1 |
| 12 | A | .4 | .2 | .6 |
| | B | — | — | — |
| | C | 4.5 | 1.1 | 5.6 |
| 14 | A | .3 | — | .3 |
| | B | .2 | .3 | .5 |
| | C | 1.7 | 1.2 | 2.9 |
| 16 | A | .2 | .1 | .3 |
| | B | .6 | — | .6 |
| | C | .5 | .8 | 1.3 |
| 18 | A | .1 | — | .1 |
| | B | .2 | — | .2 |
| | C | .6 | .3 | .9 |
| 20 | A | .3 | .1 | .4 |
| | B | .3 | .2 | .5 |
| | C | .1 | .1 | .2 |
| 22 | A | .1 | — | .1 |
| | B | .3 | .3 | .6 |
| | C | .1 | .1 | .2 |
| 24-28 | A | — | — | — |
| | B | .1 | — | .1 |
| | C | .2 | .1 | .3 |
| 30+ | A | — | — | — |
| | B | — | — | — |
| | C | — | .1 | .1 |
| Total | A | 17.3 | 5.9 | 23.2 |
| | B | 25.0 | 10.0 | 35.0 |
| | C | 101.0 | 214.7 | 315.7 |

[a]Yellow-poplar and black walnut.
[b]Red oak and ash.
[c]All other species.

## CHOOSING MANAGEMENT STRATEGIES AND EVALUATING THEIR IMPACT

The 36 management-opportunity classes and their representative stand profiles give us a framework for selecting management strategies. This general guide can be followed:

- Stands in the *< C level* stocking class are not fully utilizing their sites and cannot be expected to do so for several years. They should therefore be regenerated as soon as possible. The resulting new stands should then be cleaned and periodically thinned so as to maximize yields and promote the rapid growth of timber to a mature stage of development.
- Stands in the *C-B* stocking class are adequately stocked with acceptable trees. Decisions about treating them can normally be deferred for at least 10 years.
- Stands in the *B+* stocking class are fully stocked with acceptable trees. Improvement cuttings down to B-level stocking, followed by thinnings designed to promote the rapid growth and maturity of timber, should be undertaken.

The choice of specific strategies will vary according to product objectives and the condition of each representative stand. Consider management-opportunity class 6, representing 74,000 acres of oak-hickory forest. Suppose our objective were to grow the most mature high-quality sawtimber this stand of timber could produce in the shortest possible time, using proved methods of sound silviculture. The general strategy outlined above for stands in the < C level stocking class would be followed.

The representative stand profile for opportunity-class 6 (table 2) provides an empirical foundation for scheduling specific treatments, calculating per-acre costs, and projecting and valuing potential per-acre yields. Results are summarized in table 3.

During the next 70 years approximately 59 cords of sound timber volume worth $852 would be removed from each acre of forest land in management-opportunity class 6. About $34 would be spent on each acre for regeneration cuttings and precommercial thin-

Table 3.—*Treatment schedule for representative stand of opportunity-class 6*

| Year | Treatment | Treatment costs[a] per acre | Timber removals[b] per acre | Sawtimber included in timber removals per acre | Value of removals[c] per acre |
|---|---|---|---|---|---|
| | | *Dollars* | *Cords* | *Board feet* | *Dollars* |
| 0 | Regeneration cut | 12.70 | 8.6 | 1,600 | 75.80 |
| 10 | Precommercial cleaning | 21.50 | — | — | — |
| 30 | Commercial thinning | — | 5.0 | 0 | 12.50 |
| 42 | Commercial thinning | — | 5.0 | 0 | 12.50 |
| 52 | Commercial thinning | — | 5.1 | 900 | 24.70 |
| 62 | Commercial thinning | — | 5.8 | 1,800 | 53.00 |
| 70 | Harvest[d] | — | 29.9 | 12,000 | 673.70 |
| Total | | 34.20 | 59.4 | 16,300 | 852.20 |

[a]Based on current estimates of the expenditures required for regeneration cuttings and precommercial thinnings in the Ohio Hill Country.
[b]Basis for projecting timber removals: yield tables in Gingrich, Samuel F., 1971, Management of young and intermediate stands of upland hardwoods, NE. Forest Exp. Sta., Upper Darby, Pa. 26 p., illus. (USDA Forest Serv. Res. Pap. NE-195).
[c]Based on current estimates of the net worth of standing timber in the Ohio Hill Country.
[d]Stand was considered mature when average d.b.h. reached 15.0 inches.

nings. The cost-and-return data shown in table 3 provide a basis for estimating the economic potential of this strategy (using present net values, benefit/cost ratios, internal rates of return and other appropriate yardsticks).

For example, at a discounting rate of 5 percent, the present net worth of this proposed action would be about $81 per acre. These per-acre values provide indices for approximating the impact of treating all or any part of the 74,000 acres of oak-hickory forest in opportunity-class 6. They also give us a basis for comparing the inputs, outputs, and economic potential of this particular strategy with those of other management alternatives.

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# GROWTH POTENTIAL of the Family Camping Market

by W. F. LaPage

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

## THE AUTHOR

WILBUR F. LaPAGE is a project leader in outdoor recreation research at the U. S. Forest Service Northeastern Forest Experiment Station's Forestry Sciences Laboratory in Durham, New Hampshire. He has been conducting research on the camping market and its investment opportunities since 1964. Mr. LaPage holds a Master's degree in Forest Recreation from the University of New Hampshire and has studied social research methods at the University of Michigan's Institute for Social Research, and public administration at Syracuse University's Maxwell School of Citizenship and Public Affairs.

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# GROWTH POTENTIAL of the Family Camping Market


## ABSTRACT

A study of the camping market's short-term growth potential, based upon interviews with the heads of 2,003 representative American households. The study estimates the size of the potential camping market and divides it into three segments: those families with a high, medium and low propensity to become campers. The developed camping market is also divided into an active and an inactive segment, determined by camping participation during the 12 months preceding the survey. The total camping market is estimated to include 12.6 million active camping families, 9 million inactive, and 10 million potential camping families. Regional distributions and characteristics of each segment are described.


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"FAMILY CAMPING" is a convenient but somewhat inaccurate term for a collection of outdoor travel activities. The market is served by a large number of diverse industries: several thousand commercial and public campgrounds, several hundred manufacturers and distributors of recreational vehicles, scores of outdoor equipment suppliers, and dozens of outdoor recreation publishers. The market is highly diversified, exhibiting numerous variations in camping styles, camping equipment, and camping motivations which range from the need for an inexpensive form of travel to the desire for a priceless outdoor experience.

The market and its many segments have enjoyed sustained and vigorous growth over the past decade. As a result of this growth, there is an increasing concern that the market may be approaching a temporary saturation point —a stage in its growth where new additions are increasingly difficult to attract and hold. And unless the market can hold onto its new additions they may tend to suppress market growth through their sale of used camping equipment and their example of a less than fully satisfying experience with camping and recreation-vehicle travel.

In a study of trends in family camping participation from 1964 to 1968, each family that increased its volume of camping was offset by two other families who camped less each year (*LaPage and Ragain, 1971*). And an investment banker recently described the campground industry as approaching a level of development where "the period of rapid growth is over and individual companies' growth must be achieved largely through gains in market share" (*Peterson, 1971*).

A recent follow-up survey to the 1964-1968 trend study found that 20 percent of the panel were no longer active campers, another 33 percent showed a decreasing trend in annual number of days of camping participation from 1968 to 1971, and that another 20 percent whose camping participation was increasing quite frequently reported that they were camping more but enjoying it less. An impressive proportion (35 percent) of all panel members said that campground conditions were deteriorating and that a new breed of inconsiderate campers was taking over. These negative comments were in sharp contrast to comments made by the same campers at the start of the study in 1964.

The depth of our ignorance about the national camping market is best revealed by our inability to answer reliably one question: "How many campers are there in the United States?" Or, more importantly, how many families consider themselves to be in the camping market, whether they camped this year or not? Without an answer to this question, most estimates of market growth are little more than guesses.

National surveys of outdoor recreation participation in 1960 and in 1965 indicated that about 8 percent of the adult population (12 years or over), or about 13 million adults and children, were campers in 1960, and that about 10 percent of the adults, or 18 million adults and children, camped in 1965 (*Bureau of Outdoor Recreation, 1967*). An extension of this 38-percent growth rate to the second half of the decade would result in a projection of 25 million campers by 1970.

At the First Camping Congress in June, 1971, estimates of the total number of campers (adults and children) ranged from 33 million to 50 million (*Dunlap, 1971; Smith, 1971; Booth, 1971*). One estimate presented at that congress was that there were 3.5 million recreational vehicles in use and 4.5 million tent camping families, for a total of 8 million camping families. Another estimate set the figures at 7.8 million adults (3.9 million families?) who camped in recreation vehicles, and 12 million adults (6 million families?) who camped in tents (for a total of 10 million camping families?). No one knows whether the estimated 8 or 10 million families who camped in 1970 were 50 percent or 99 percent of the total camping market!

In November, 1971, through the combined efforts of government and private enterprise, an effort was made to answer some of these questions. In a nation-wide probability sam-

ple, 2,003 heads of households were interviewed to determine the existing size and short-term growth potential of the family camping market. If a household had been in the camping market and had left it, we wanted to know why. And from those still in the market we collected a number of measures of the volume and trend of camping participation. Finally, we asked the heads of non-camping households to estimate the likelihood of their entering the family camping market during the next 4 to 5 years.

The term "household" is used in the Census Bureau's definition: "all persons who occupy a 'housing unit.'" A single person living alone is a household. Heads of households were asked about their own, and their spouse's, camping experience and equipment; activities of other members of the household, in which either head did not participate, were not covered. Thus "family camping," as used in this study, would include a group of men hunting or fishing together but might not include a group of camping students living at home.

## HIGHLIGHTS OF THE SURVEY

### Defining the Market

Past national surveys of participation in outdoor recreation have tended to treat camping as just one of a long list of outdoor activities, rather than as the means by which many other activities are enjoyed. Participation in camping is prerequisite to part of the reported activity in boating, hiking, fishing, swimming, sightseeing, driving for pleasure, and numerous other activities that can best be enjoyed in and around campgrounds. Many past surveys have failed to differentiate clearly between such activities as wilderness camping, family camping at developed sites, recreational vehicle travel, cabin camping, youth camping, and church camping.

In order to be certain that we were measuring the size and growth potential of the family camping market as we defined it, and not some of these other types of camping, this survey used line drawings of several different types of familiar camping equipment—items such as tents, camping trailers, pick-up campers, and motor homes. Heads of households were not asked if they had ever camped, but if they had ever taken an overnight trip with their families or friends using any of the depicted items of equipment. This approach was used to minimize over-counting from cabin campers, youth campers, etc., as well as to avoid under-representing the hunters and fishermen who may use camping equipment on overnight trips but do not consider themselves campers.

### The Developed Camping Market

The survey findings suggest that the camper market is substantially larger than any of the Camping Congress estimates (table 1). More than 12.6 million households (40.2 million persons) were estimated to have camped in the 12 months preceding the survey. And over 9 million more households (29.1 million persons) had camped at some time in the past, but not during the past 12 months. For the households that had camped during the past year, the median level of participation was seven nights away from home on two separate camping trips.

The survey disclosed a relatively high level of equipment renting and borrowing. For their most recent trip, 11 percent of all campers (active or inactive in 1971) had rented their equipment, and 35 percent had borrowed it. This multiple use of equipment may explain why this survey's estimate of market size is higher than many past estimates based on production and sales figures of recreational vehicles and camping equipment.

### The Potential Camping Market

A larger developed camper market might logically suggest a smaller potential camper market to draw upon. There has been almost no research on the size of the potential camping market. However, a 1960 nationwide survey of outdoor recreation interests provides a partial comparison of public interest in camping over the past decade (table 2).

Table 1.—Highlights of the 1971 camper market survey of 2,003 heads of households

| Head of household | Survey | Estimated households[a] | Estimated persons[b] |
|---|---|---|---|
| | *Percent* | *Millions* | *Millions* |
| 1. Has camped with family or friends: | | | |
| a. During the past 12 months | 19.4 | 12.6 | 40.2 |
| b. At some time in the past, but not in the past 12 months | 14.0 | 9.1 | 29.1 |
| 2. Has never camped with family or friends but family: | | | |
| a. Plans to in 1972 | 2.7 | 1.8 | 5.5 |
| b. Hopes to try it, 2-5 years | 8.6 | 5.6 | 17.9 |
| c. May try it in 2-5 years | 4.0 | 2.6 | 8.3 |
| 3. Is not likely to go camping | 51.3 | 33.3 | 106.3 |
| Total | 100.0 | 65.0 | 207.3 |

[a]Based on an estimated 65 million households in 1971, projected from 1964-1969 data. Statistical Abstract of the U.S., 1970.

[b]Based on an estimated 3.19 persons per household (1969 data). Statistical Abstract of the U.S., 1970.

Table 2.—A comparison of camping interests in two national surveys

| Item | 1960[a] | 1971 |
|---|---|---|
| | *Percent* | *Percent* |
| Has camped in the past year | 15 | 19 |
| Has camped, but not in past year | (not asked) | 14 |
| Has never camped, or has not camped in past year, but would like to do so in the future | 9 | — |
| Never camped, but may try it in future | — | 15 |
| Never camped and not interested, no answer | 76 | 51[b] |
| Basis: sample size | 2,759 | 2,003 |

[a]From ORRRC 1962. Participation in Outdoor Recreation: Factors Affecting Demand among American Adults, Study Report 20, Outdoor Recreation Resources Review Commission.

[b]For an estimate of the proportion of the population with no potential for entering the camping market, those households that have camped in the past but have permanently given up camping should be added to this figure. If we assume that campers who have not camped for 3 years or more are permanently out of the market, then two-thirds of the inactive campers should be added, and the nonmarket group would increase from 51 to 61 percent.

A casual inspection of table 2 might suggest that the potential camping market grew from 9 percent of the population in 1960 to 15 percent of the population in 1970. A closer look at both studies will reveal a slightly different picture. Actually, as is shown in table 1, less than 3 percent of those interviewed in 1971 expressed a strong interest in taking up camping as a leisure activity. Another 8-1/2 percent said that they hoped to try it in the future. Since not all of these expectations will produce campers, something less than 11-1/2 percent of the 1971 sample represent potential market additions. Furthermore the 1960 O.R.R.R.C. survey failed to distinguish between those who had never camped and those who had not camped in the past year. Consequently the 9 percent in 1960, who had camping aspirations includes some who were already in the camping market. However, the O.R.R.R.C. report indicates that the 9 percent is mostly made up of people who have not yet had their first camping experience (*O.R.R.R.C., 1962*, pages 7 and 62).

Obviously, by 1971 many more people had been exposed to camping equipment, camping advertising, camping neighbors and friends, and popular literature depicting camping as a pleasurable and low cost leisure activity. This increased exposure has undoubtedly had an impact on the size of both the potential and the active camper market segments.

## Recent Camping Trends

The distribution of years of camping experience, for all campers, reveals the "newness" of the camping market and indicates that camp-

ing has continued to attract sizable numbers of new campers in recent years:

| *Year began camping* | *Percent* |
|---|---|
| Don't recall | 11 |
| Before 1949 | 10 |
| 1950-1959 | 16 |
| 1960-1965 | 21 |
| 1966-1969 | 25 |
| 1970 | 9 |
| 1971 | 8 |
| | 100 |

Although the market appears to be expanding rapidly by adding new campers, the average number of days that each camper camps is either decreasing or remaining relatively constant. Campers who had been in the market for at least two years were asked if their camping participation had been increasing or decreasing during the past few years. Only 16 percent reported an increase, as opposed to 37 percent who reported decreasing participation and 25 percent whose participation was either constant or highly variable. The proportion of approximately 1 increasing to 2 decreasing campers coincides with the trends found in a long-term panel study of camping participation (*LaPage and Ragain, 1971*).

Campers with at least 2 years of camping experience were also asked whether they had noticed any major changes in the condition of campgrounds, in the costs of camping, or in the types of people who go camping. The most commonly mentioned changes, and the frequency with which they were reported, are:

| | *Percent* |
|---|---|
| Improved facilities, services | 32 |
| Increased costs | 24 |
| More campers, over-crowding | 22 |
| Less desirable campers | 12 |
| No changes | 12 |
| Don't use campgrounds, haven't been lately | 9 |
| More campgrounds available | 6 |
| Dirty campgrounds | 5 |
| More expensive equipment | 4 |
| Campers more congenial | 4 |

For their most recent camping trip, about half the campers used tents and half used some type of camping vehicle (table 3). Asked about their next purchase, 5 percent of active and inactive campers said they planned to buy a tent and 16 percent said they intended to purchase a camping vehicle (camping trailer, 2 percent; travel trailer, 4 percent; truck camper, 5 percent; pickup cover, 1 percent; motor home, 3 percent; and van conversion, 1 percent).

Table 3.—Type of equipment used on last camping trip by all households[a] that have camped, and how acquired for that trip[b]

| Equipment | Used on last camping trip and: | | | |
|---|---|---|---|---|
| | Rented | Borrowed | Purchased | Already Owned |
| | *Percent* | *Percent* | *Percent* | *Percent* |
| Tent | 4 | 18 | 6 | 22 |
| Camping Trailer | 3 | 4 | 2 | 4 |
| Travel Trailer | 3 | 4 | 1 | 9 |
| Truck Camper | 1 | 5 | (*) | 9 |
| Pick-up Cover | (*) | 1 | (*) | 5 |
| Motor Home | (*) | 1 | 0 | 2 |
| Van Conversion | 0 | 2 | 1 | 3 |

[a]Includes active and inactive campers in the 1971 survey.

[b]Totals do not add to 100 percent because some campers use more than one type of equipment on a single trip.

*Less than half of 1 percent.

### The Existing Camper Market

The camping market is usually defined arbitrarily as those persons who have camped during the past year. To estimate sales potential, it might be more realistic to consider a somewhat larger market, including those people who intend to start camping in the next year as well as those who may have only temporarily dropped out of the market. About 6-1/2 percent of the campers in a recently reported panel study failed to camp in any one year over a 5 year period (*LaPage and Ragain, 1971*). Although the 1971 survey cannot readily identify the point at which temporary market losses become permanent losses, about one-third of the inactive campers, that is households that have not camped in the past year, have failed to camp in the past 2 years:

| *Years since last camped* | *Percent of all camping households* | *Percent of inactive camping households* |
|---|---|---|
| 0 | 58 | — |
| 1 | 4 | 10 |
| 2 | 10 | 24 |
| 3 | 7 | 17 |
| 4-5 | 8 | 19 |
| 6-9 | 4 | 9 |
| 10+ | 8 | 18 |
| Don't know | 1 | 3 |
| | 100 | 100 |

The probability of returning to the market undoubtedly diminishes with each additional year away from camping; the bulge in the distribution at 2 years might indicate that 2 years is the break point—including some temporary and some permanent market losses. That is, a 1 or 2-year gap is probably a temporary drop in activity for most people, but those who have been out of the market for 3 or more years may tend to become permanent losses. If we assume from table 1 that one-third of the inactive campers (9.7 million) are only temporarily inactive, and that all non-campers who are planning to camp next year (5.5 million) do as planned, there would be an estimated 55.4 million persons in the camping market.

Although the camping market is undoubtedly larger than its currently active segment, only that segment was analyzed in the survey for the obvious reason that it alone can provide current participation data.

Of all camping heads of households surveyed, 13 percent reported that they do not participate in family camping. (The comparable figure for the active market segment is 8 percent.) That is, they have no families, or camp with friends, or use their camping equipment for hunting and fishing trips exclusively. This is probably a larger portion of the active camping market now than it was in 1960, and it may become increasingly important in campground planning and management.

Reported campground patronage during the 12 months preceding the survey indicates a slight disadvantage to commercial campgrounds (table 4). Forty percent of active campers had not visited a commercial campground, but only 24 percent had failed to visit a public campground. And 27 percent of active campers had visited at least two public campgrounds, while only 16 percent had visited two or more commercial developments. The "advantage" to public campgrounds may be somewhat exaggerated by these figures because the average visit is longer at commercial campgrounds (most public campgrounds have a limit). Also, most wilderness and back-country camping is done on public lands and might be reported in these figures as having been done on public "campgrounds".

Table 4.—Visits to commercial and public campgrounds by active camping households in 1971

| No. of campgrounds visited in 1971 | Type of campground visited | |
|---|---|---|
| | Commercial | State or Federal |
| | *Percent* | *Percent* |
| 1 | 22 | 28 |
| 2-5 | 16 | 27 |
| 6 or more | 9 | 9 |
| None | 40 | 24 |
| Don't recall | 13 | 12 |
| Total | 100 | 100 |

Although there are many campers in the active market, the median level of participation

is low, both in terms of trips and in terms of days camped. More than half of 1971's active campers made only one or two trips and camped less than 8 days:

| *Trips* | *Percent of campers* | *Days* | *Percent of campers* |
|---|---|---|---|
| 1 | 38 | 1-2 | 20 |
| 2 | 17 | 3-5 | 21 |
| 3 | 12 | 6-7 | 11 |
| 4-5 | 12 | 8-30 | 35 |
| 6-9 | 7 | 31+ | 10 |
| 10+ | 14 | Don't know | 3 |

Applying these participation rates to the estimated 12.6 million camping households (table 1) produces an estimated 53.5 million trips and 519 million camper-days in 1971. The weighted average participation rate was four camping trips and 13 days of camping per household.

The number of households in the active camper market, and in the inactive market, increases from East to West; 54.3 percent of households in the Western States have camped at some time in the past versus 21.5 percent in the Northeast (table 5). Similarly, households with higher incomes are more likely to be campers; 44.1 percent of the households with a gross 1970 family income in excess of $15,000 have camped at some time in the past, versus 23.2 percent of those households with less than $5,000 gross income (table 6).

Table 6.—Households in the active and inactive camping markets, by income classes

[Percentage of all households]

| 1970 Income[a] | Inactive | Active |
|---|---|---|
| Under $5,000 | 12.3 | 10.9 |
| $5,000 to $6,999 | 8.8 | 19.7 |
| $7,000 to $9,999 | 15.6 | 20.7 |
| $10,000 to $14,999 | 16.3 | 23.5 |
| $15,000 or more | 16.3 | 27.8 |
| U.S. | 14.0 | 19.4 |

[a]Total family income in 1970 before taxes.

Table 5.—Households in the active and inactive camper markets, by region

[Percentage of all households]

| Region[a] | Inactive | Active |
|---|---|---|
| Northeast | 8.8 | 12.7 |
| North Central | 14.0 | 21.1 |
| South | 13.8 | 15.7 |
| West | 21.7 | 32.6 |
| U.S. | 14.0[b] | 19.4[b] |

[a]U.S. Census Bureau regions, containing the following approximate number of households: Northeast, 15.6 million; North Central, 17.5; South, 19.5; and West, 12.4. Regions include:

| | |
|---|---|
| Northeast: | Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania |
| North Central: | Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas |
| South: | Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas |
| West: | Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California. |

[b]From table 1.

Ten percent of the active camper market rented camping equipment at least once during 1971. Equipment renting was most common among heads of households in the 30-39 year age group, people with professional and managerial occupations, those with some college background, and those with incomes of $15,000 or more.

Twenty percent of the active market made purchases of $100 or less for camping equipment in 1971; 9 percent spent over $100. Also, 2 percent of the inactive campers spent up to $100 on camping equipment even though they did not use it in 1971.

Total expenditures while on 1971 camping trips, for items such as camping fees, tolls, gasoline, meals, and groceries, ranged from $0 reported by 5 percent to over $250 for 17 percent of the active camping households in the sample:

| *1971 trip expenditures* | *Percent of active Camping households* |
|---|---|
| Nothing | 5 |
| $50 or less | 25 |
| $51 to $100 | 16 |
| $101 to $250 | 18 |
| $251 or more | 17 |
| Don't know | 19 |

In most respects, the active camper market is not representative of a cross section of American households. On the average, heads of households in the active camping market tend to be younger, better educated, and have higher incomes than the public at large (see Appendix). There are fewer non-whites in the camping market than in the population, and fewer residents of metropolitan areas with one million or more inhabitants.

Among currently active camping households who have camped for at least the past two years, 26 percent reported that their camping participation had been increasing, and 21 percent that it had been decreasing; 43 percent expected to camp more often during the next 2 to 3 years, while 12 percent predicted a decrease. Of the inactive campers, 60 percent had been camping less and predicted a continued decrease in their camping participation. Nineteen percent of the inactive campers expressed a desire to camp more often in the future.

Both increases and decreases in camping participation were frequently explained by changes in the family's life cycle. For example, 5 percent of the active households, and 11 percent of the inactive group, explained decreases in camping on grounds of "having babies or children who are too young to camp", "family grown now", or "getting too old". And 15 percent of active households and 9 percent of inactive households explained increases by such reasons as "our children are older" and "we have more time now."

## The Potential Camping Market

The potential camping market could be treated as a single group of households comprising about 15 percent of the population (table 1). In fact, however, this group can be readily divided into three sub-groups: 1.8 million households with a *high potential* for entering the market because they have already considered it and planned to try camping "next year"; 5.6 million households with *moderate potential*, because they have considered camping in the past and expect to try it in the future; and a *low potential* group of 2.6 million households in which, although the idea of camping has not been seriously considered in the past, the head of the household indicated that camping was a possibility during the next 5 years.

To promote market expansion, the most important households to concentrate on are the 7.3 million with high and moderate market potential. These people have considered camping in the past and see themselves as campers at some time in the future. However, a closer look at all three segments of the potential camping market is necessary for an understanding of total market potential.

The geographic distribution of the potential camping market's 10 million households is in sharp contrast to the distribution of the existing market; the bulk of potential market growth appears in the Northeast and North Central regions (table 7). Not only is the percentage of people who expressed a desire to try camping much higher in these two regions, but their population bases are, at present, much higher than that of the western region. In the West, 63.4 percent of the households (7.9 million) are either ex-campers, currently active campers, or potential campers. The North Central region has a lower proportion (53.9 percent) but a larger number (9.4 million) of its households in these same three categories.

The largest potential for camping market expansion, in all regions, exists in households earning $7,000 to $10,000 annually. However, a large number of families above and below

Table 7.—Households in the potential camping market, by region

[Percentage of all households]

| Region[a] | High[b] camping potential | Moderate[c] camping potential | Low[d] camping potential | Total |
|---|---|---|---|---|
| Northeast | 3.1 | 11.0 | 3.9 | 18.0 |
| North Central | 2.6 | 12.3 | 3.9 | 18.8 |
| Southern | 3.5 | 4.9 | 5.6 | 14.0 |
| Western | 2.3 | 5.9 | .9 | 9.1 |
| U.S.[e] | 2.7 | 8.6 | 4.0 | 15.3 |

[a]See table 5 for definitions.
[b]Planning to go camping in 1972.
[c]Would like to try camping in 1 to 5 years.
[d]May become campers in 1 to 5 years.
[e]From table 1.

Table 8.—Households in the potential camping market, by income classes

[Percentage of all households]

| Gross 1970 income | High camping potential | Moderate camping potential | Low camping potential | Total |
|---|---|---|---|---|
| Under $5,000 | 2.3 | 3.8 | 3.1 | 9.2 |
| $5,000 to $6,999 | 2.1 | 9.3 | 4.3 | 15.7 |
| $7,000 to $9,999 | 5.7 | 11.4 | 4.4 | 21.5 |
| $10,000 to $14,999 | 2.4 | 10.8 | 2.4 | 15.4 |
| $15,000 or more | 2.8 | 11.7 | 5.0 | 19.5 |
| All income classes | 2.7 | 8.6 | 4.0 | 15.3 |

this income level are already campers, and many more would like to become campers (table 8).

Because most of the households with low potential for entering the market had not seriously considered camping before they were interviewed, the following descriptions and comparisons refer only to households with high or moderate potential for entering the market during the next 5 years. Those having low camping potential (4% of the households) have been combined with the 51 percent (from table 1) who were either unlikely to try camping or definitely not interested in it.

Among the non-camping households who expressed a desire to start camping (the high and moderate potential group), 25 percent indicated a preference for tents, and 63 percent expect to use some type of camping vehicle (camping trailer, 12%; travel trailer, 16%; truck camper, 18%; pick-up cover, 5%; motor home, 8%; and van conversion, 4%). Thirty-one percent expect to rent the equipment for their first trip, 18 percent will borrow, 28 percent will probably purchase, and 5 percent already own it.

These households, as a group, exhibit a number of characteristics that distinguish them from the larger non-market group. In many cases, these characteristics validate our measures of market potential by revealing different interests in outdoor activities. Other characteristics point to the group's ability to move from potential participation to actual involvement. And still other differences identify some of the ways in which it may be possible to reach the potential camping market through focused advertising and promotion.

Potential campers tend to share more family leisure activities than either the total U.S. public or that segment of the public which is less interested in camping (table 9). And those shared activities are much more likely to be oriented toward the out-of-doors. Fishing, for example, was reported to be a family activity by 16 percent of the total sample, by 11 percent of those not interested in camping, and by 27 percent of the potential campers. Water sports (boating and water skiing) follow the same pattern. Picnics and cook-outs were reported to be a family activity by 10 percent of the sample, by 7 percent of those less interested in camping, and by 18 percent of the potential camping market.

Although the percentages change, a similar pattern governs other activities such as vacation travel, hunting, hiking, winter sports, and recent purchases of outdoor sports equipment. Television viewing, on the other hand, was reported as a shared leisure activity by 17 percent of those who are less interested in camping, but by only 4 percent of the potential campers. This may not mean that they watch television less, but that they are less likely to consider it as a family activity.

Attendance at a camping show, boat show, or similar exhibition of outdoor equipment during the past 2 years was twice as common among potential campers as among those who have little interest in camping. Nearly the same pattern emerges for visits to city, county, state and national parks (table 9).

Potential camping households are much more likely to have a vehicle available to facilitate their camping interest, but they are also more likely to be tied to a second, or vacation, home. However, a comparable proportion of active campers also own second homes.

Compared with the households who are less interested in camping, potential campers receive more magazines in the home. And, those magazines clearly reflect the diversity of their interests (table 9). The common characteristic of potential camping households seems to be a high level of interest in a variety of family-oriented leisure activities.

Table 9.—A comparison of leisure interests and activities among the general public, potential campers, and households with little or no potential for camping (in percent)

| Item | Total U.S. Public | Potential additions to camping market | Little or no interest in camping |
|---|---|---|---|
| Shared leisure activities:[a] | | | |
| Fishing | 16 | 27 | 11 |
| Water sports | 16 | 27 | 11 |
| Winter sports | 4 | 8 | 1 |
| Hunting | 4 | 6 | 2 |
| Picnics-cookouts | 10 | 18 | 7 |
| Travel-vacation | 14 | 23 | 13 |
| Walking-hiking | 4 | 7 | 3 |
| Television viewing | 13 | 4 | 17 |
| Movies-theatre | 10 | 15 | 8 |
| None shared | 19 | 9 | 24 |
| Recent visits to: | | | |
| Camping-boat show | 22 | 34 | 10 |
| City-county park | 59 | 74 | 47 |
| State park | 46 | 53 | 31 |
| National park | 33 | 35 | 21 |
| National monument | 22 | 25 | 15 |
| National seashore | 38 | 30 | 22 |
| National forest | 23 | 21 | 12 |
| None of these | 25 | 9 | 37 |
| Recent recreation equipment purchases: | | | |
| Fishing | 10 | 13 | 6 |
| Hunting | 4 | 7 | 2 |
| Winter sports | 3 | 6 | 2 |
| Lawn and court games | 12 | 21 | 12 |
| Boats | 3 | 5 | 1 |
| None purchased | 47 | 34 | 62 |
| Magazines regularly received: | | | |
| News | 33 | 38 | 29 |
| Sports | 10 | 11 | 6 |
| Home-garden | 17 | 23 | 14 |
| Hobbies-crafts | 3 | 5 | 1 |
| Women's | 24 | 29 | 20 |
| Clubs-associations | 3 | 4 | 2 |
| None at all | 28 | 20 | 36 |
| Owns, or has the use of: | | | |
| 2 or more autos | 44 | 55 | 31 |
| No car or truck | 16 | 7 | 23 |
| Vacation home | 10 | 16 | 6 |

[a]The incidences of many of these activities among the total U.S. public, as reported in our survey, differ noticeably from those given in the 1962 report of the Outdoor Recreation Resources Review Commission, the 1967 *Trends in Outdoor Recreation*, by the Bureau of Outdoor Recreation, and the most recent B.O.R. survey as reported in *U.S. News and World Report*, April 17, 1972. The differences are probably due to survey methodology. Each of these other surveys presented a list of activities to a sample of adults, whereas this study asked for *shared* family activities, and did not use a prepared list of possibilities. The 1971 B.O.R. survey found 22 percent of the population, 9 years or older, to be campers—compared with 19 percent of the households in the 1971 Forest Service study who were active campers.

### Implications of the 1971 Camper Market Survey

The sustained growth of the camping market during the past decade implies expansion of the inactive, and shrinkage of the potential, segments of that market. The documentation that an inactive segment exists and is nearly equal in size to the active segment of the market is a major finding of this study. The effect of the inactive segment on future market growth can only be guessed at. Questions of when inactivity is temporary and when it is permanent, its causes, and the interrelationships among those causes, cannot be adequately answered by this study. The question of how much market "drop-out" is due to normal attrition and how much is due to unsatisfactory conditions should be of major concern to the industry.

The growth of the inactive segment from an apparently insignificant number in 1960 (*O.R.R.R.C., 1962*), to 9 million households in 1971 raises another important question that affects the viability of the potential market. If a large number of these campers are market losses due to accelerated attrition resulting from a frivolous response to advertising, then perhaps a comparable portion of our measured potential is equally frivolous.

The procedures used for identifying potential market additions seem to be validated by the consistently higher frequencies of family-oriented and outdoor-oriented leisure activities found in the potential camper segment. However, this same hyperactive segment of the population may constitute the bulk of the potential growth in many markets other than camping—some of which might be competitive with camping. Further, their involvement in a wide array of interests probably also means that this group might be looking for high quality camping experiences and will be difficult to hold in the market if camping fails to measure up to its advertised image.

The concentration of potential campers in the Northeastern and North Central regions should be encouraging to the commercial campground industries of those states, but may be a cause for alarm to managers of some already heavily-used public sector campgrounds.

At least 51 percent of the households sampled apparently have little or no interest in camping. This figure may be as high as 61 percent if the permanently inactive former camping households are included. Whether any of this segment of the population can eventually provide added market growth is probably a direct function of the camping industry's ability to diversify. Obviously these people have been exposed to many of the promotional and social stimuli that have caused others to become interested in camping and have not responded. Consequently, a new image of camping, or perhaps a new approach to selling an older style of camping (emphasizing simplicity and minimizing expensive gadgets), may be the best way to add a major new growth surge from this huge reservoir of households that have apparently "tuned out" present camping styles.

A major implication of a large and expanding inactive segment of the camper market is its resultant creation of a subsidiary market for second-hand camping equipment. Careful monitoring, in the years ahead, of production and sales statistics for new camping vehicles should reveal whether the inactive segment of the market is stabilizing, declining, or growing in proportion to total market growth.

### Recommendations for Market Expansion

Any improvement in understanding individual market segments logically leads to questions of how these segments can best be reached and served. Broad-spectrum, industry-wide advertising for camping (for example: "Go camping—for the fun of it!") can certainly be improved upon with a little knowledge about market segments. We know, for example, that households with high and moderate potential for becoming campers (by definition) have been thinking about going camping, but have been putting it off. A highly relevant promotional message could encourage them to go ahead and try it with rented equipment, or at a campground "open house".

A major industry-wide effort, carefully focused on specific market segments, might have such objectives as encouraging active campers to camp more, inactive campers to give it another try, potential campers to stop delaying, and low-potential noncampers to take a look and see what camping is really all about. If such an effort were mounted, it would be highly desirable to follow it with an evaluation similar to the 1971 survey to determine its effectiveness.

If market saturation appears to be approaching after such an intensive promotional effort, that would probably be an appropriate time to re-evaluate the roles of public agencies in the camping market.

Although it is seldom recognized, public agencies have clearly served as an industry-wide loss leader. That is, low-cost public camping provides the stimulus for many campers to buy equipment and enter the market. Then, as their interests shift to more sophisticated camping, their patronage of public developments declines and they seek the greater convenience and variety of commercial campgrounds. This role could probably be strengthened and expanded to the benefit of the total market. One obvious way of expanding it is for public campground managing agencies to make a major commitment to provide outdoor opportunities for economically disadvantaged groups. And as the spending power of these groups increases, many may move into the market for more expensive forms of camping. As this survey has shown, there is a definite camping potential among families at lower income levels.

For the majority of public campgrounds, which are too remote from population centers to serve as camping "training grounds," a number of other role definitions are possible. The generally stated policy of providing minimal services at public campgrounds is not, in many instances, accurately reflected in the cost of developing those campgrounds. At costs per site of up to $3,000, more than minimal services are being offered. At those locations where an established clientele exists, public-private cooperation through lease arrangements is an obvious opportunity. At other locations, a role reversal, with the public campground serving as an overflow for nearby commercial campgrounds, may be a logical development in keeping with the broader social goals of stimulating rural economies and expanding the range of services available on public recreational lands.

The finding that 13 percent of all camping heads of households do not camp with their families invites speculation about a possibly emerging non-family camping market, and about what the industry's appropriate response might be. Solitary campers, unrelated groups, and hunters and fishermen probably make up the bulk of this segment. And, while they may provide only a minor economic contribution to the total market, many persons introduced to camping in other than a family situation may eventually join and contribute to the mainstream of the camping market. A related finding is that 13 percent of the potential camping market, and 22 percent of the active market, are single heads of households; some of these people may be looking for something other than the conventional family camping experience.

In view of the fact that many campers explained recent trends in their participation (either up or down) by various changes in their life situations, the opportunity to promote camping as one of the lifetime "sports" seems excellent. The great adaptability of camping to diverse interests, age groups, and family cycle stages, should be a relatively easy concept to promote.

Probably the single most difficult and most important problem facing the camping industry today is camping's slipping image. Comments such as "too many people," "inconsiderate campers," "overcrowding at campgrounds," and "dirty campgrounds," are too frequent and too serious to ignore.

This is an industry-wide problem. But at its present stage of development, the industry is probably not equipped to deal effectively with it, although a number of organizations are attempting to attack the problem. The several programs of the North American Family Camper's Association are probably the most outstanding effort in this field. These programs involve regional leadership conferences for campers, occasional extension-type beginners' courses in equipment usage and how to camp, and an extensive literature program on

good camping manners. Much of this material could easily be expanded and made available to a wider audience through television and through adult education courses co-sponsored by public agencies, camper organizations, and equipment manufacturers. Another approach would be a vigorous federal program of technical and financial assistance to commercial campgrounds to improve the quality of camping experiences.

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■

## DEMOGRAPHICS OF THE CAMPING MARKET

| Characteristics | U.S. public[a] | Camping households | | |
|---|---|---|---|---|
| | | Active | Inactive | Potential[b] |
| *Head of household:* | *Percent* | *Percent* | *Percent* | *Percent* |
| 18-29 years of age | 26 | 43 | 30 | 40 |
| 30-39 | 17 | 21 | 15 | 28 |
| 40-49 | 18 | 17 | 21 | 17 |
| 50-59 | 15 | 13 | 14 | 8 |
| 60 years or over | 23 | 5 | 20 | 7 |
| Less than high school complete | 41 | 25 | 30 | 30 |
| High school complete | 36 | 41 | 41 | 42 |
| Some college | 23 | 34 | 28 | 27 |
| Professional | 12 | 18 | 14 | 15 |
| Managerial | 10 | 12 | 10 | 10 |
| Clerical, sales | 12 | 14 | 17 | 12 |
| Craftsman, foreman | 17 | 25 | 19 | 19 |
| Other manual, service | 23 | 18 | 16 | 32 |
| Farmer, farm laborer | 3 | 2 | 3 | 4 |
| *Household:* | | | | |
| Non-Metro - rural | 11 | 13 | 8 | 9 |
| urban | 21 | 26 | 26 | 21 |
| Metro - 50,000-999,999 | 27 | 27 | 28 | 25 |
| 1,000,000 or over | 41 | 34 | 37 | 45 |
| Northeast | 25 | 16 | 16 | 30 |
| North Central | 28 | 31 | 28 | 36 |
| South | 30 | 24 | 29 | 22 |
| West | 17 | 29 | 27 | 12 |
| Under $5,000 income | 29 | 16 | 25 | 13 |
| $5,000 - $6,999 | 12 | 12 | 7 | 12 |
| $7,000 - $9,999 | 18 | 19 | 20 | 20 |
| $10,000 - $14,999 | 22 | 26 | 25 | 25 |
| $15,000 or over | 17 | 24 | 20 | 21 |
| White | 88 | 95 | 96 | 87 |
| Nonwhite | 12 | 3 | 4 | 12 |
| No children in household | 49 | 37 | 49 | 24 |
| With children under 18 | 50 | 63 | 49 | 76 |
| Own home | 65 | 65 | 66 | 67 |
| Rent home | 35 | 34 | 33 | 33 |
| Percent of sample (2,003 households) | 100 | 19 | 14 | 11 |

[a]Based on a sample of 2,003 households surveyed in December, 1971.
[b]Does not include low potential group; another 4% of the population.

## Reliability of survey percentages

Results of any sample are subject to sampling variation. The magnitude of the variation is measurable and is affected by the number of interviews and the level of the percentages expressing the results.

The table below shows the possible sample variation that applies to percentage results reported from the Opinion Research Corporation sample. The chances are 95 in 100 that a survey result does not vary, plus or minus, by more than the indicated number of percentage points from the result that would be obtained if interviews were conducted with all persons in the universe represented by the sample.

| *Size of sample on which survey result is based* | *Approximate sampling tolerances applicable to percentages at or near these levels* | | |
|---|---|---|---|
| | *10% or 90%* | *30% or 70%* | *50%* |
| 2,000 interviews | 2% | 3% | 3% |
| 1,000 interviews | 2% | 4% | 4% |
| 500 interviews | 3% | 5% | 5% |
| 250 interviews | 5% | 7% | 8% |
| 100 interviews | 7% | 11% | 12% |

## Sampling Tolerances When Comparing Two Samples

Tolerances are also involved in the comparison of results from different parts of any one sample. A difference, in other words, must be of at least a certain size to be considered statistically significant. The table below is a guide to the sampling tolerances applicable to such comparisons.

| *Sizes of samples being compared* | *Differences required for significance[a] at or near these percentage levels:* | | |
|---|---|---|---|
| | *10% or 90%* | *30 or 70%* | *50%* |
| 1,000 and 1,000 | 3% | 5% | 6% |
| 1,000 and 500 | 4% | 6% | 7% |
| 500 and 500 | 5% | 7% | 8% |
| 500 and 200 | 6% | 9% | 10% |
| 200 and 200 | 7% | 11% | 12% |
| 200 and 100 | 9% | 14% | 15% |
| 100 and 100 | 10% | 16% | 17% |

[a]At the 95% probability level.

SECTION C

The next group of questions concerns your leisure interests and your possible interest in vacation travel and family camping.

SHOW EXHIBIT C-1

C1. Have you ever gone on an overnight trip with your family, or with friends, and used any of the types of equipment shown on this card? Do not include any camping trips you took with scouting groups, or while you were in the military service.

1 YES → SKIP TO Q. C5
2 NO
3 DON'T KNOW

(IF "NO" ON Q. C1, ASK):

C2. Have you, or has your spouse, ever considered going on such a trip?

1 YES
2 NO → SKIP TO Q. C4
3 DON'T KNOW

(IF "YES" ON Q. C2, ASK):

SHOW EXHIBIT C-3

C3. Which one of the statements on this card best describes your family's present attitude toward camping? Just read me the number, please.

1 2 → SKIP TO Q. C21

3 4 5 DON'T KNOW → SKIP TO Q. C24

(IF "NO" ON Q. C2, ASK):

C4. Would you say that it is likely or not likely that you might go camping with your family some time in the next 4 - 5 years?

1 LIKELY
2 NOT LIKELY
3 DON'T KNOW

NOW SKIP TO Q. C24

SHOW EXHIBIT C-1 AGAIN

C5. These are silhouettes of several kinds of camping equipment. Which of these is most like the equipment you used for your last such trip? Just read me the letter, please.

A. TENT →

C6a. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW

B. CAMPING TRAILER (Folding) →

C6b. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW

C. TRAVEL TRAILER (Any kind, any size) →

C6c. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW

D. TRUCK CAMPER →

C6d. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW

E. PICK-UP COVER →

C6e. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW

F. MOTOR HOME →

C6f. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW

G. VAN CONVERSION →

C6g. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW

X. OTHER (Please specify): _____ →

C6x. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW

Y. DON'T KNOW

C7. During the past 12 months, how many camping trips did you go on?

_____ # OF TRIPS

X NONE
Y DON'T KNOW

(IF "NONE" ON Q. C7, ASK):

C8. About how many years ago did you take your last camping trip?

_____ YEARS AGO

X DON'T KNOW

NOW SKIP TO Q. C12

C9. In total, how many nights were spent away from home on these _____ trips?

_____ # OF NIGHTS

X NONE
Y DON'T KNOW

C10. In total, how many different privately owned and how many federal or state government owned campgrounds did you stay at while on the _____ trips?

_____ PRIVATELY OWNED

X NONE
Y DON'T KNOW

_____ GOVERNMENT OWNED

X NONE
Y DON'T KNOW

C11. Approximately how many of these _____ trips were predominantly family camping or vacation travel trips, how many were for hunting and fishing, and how many were business trips at least in part?

_____ # FAMILY CAMPING AND VACATION TRAVEL

_____ # HUNTING AND FISHING

_____ # BUSINESS TRIPS

X DON'T KNOW

C12. In what year did you begin camping as a family?
(INTERVIEWER: IF "NEVER", CIRCLE "Y" AND ASK: "When did you, yourself, begin camping?")

_____ YEAR

X DON'T REMEMBER
Y NEVER CAMPS WITH FAMILY

INTERVIEWER: IF "1970" OR EARLIER, ASK Q. C13 – C17. IF "1971", SKIP TO Q. C18.

(IF "1970" OR EARLIER ON Q. C12, ASK):

C13. Do you camp about the same number of nights each year, or has your participation in camping been increasing or decreasing during the past few years?

1 SAME
2 INCREASING
3 DECREASING
4 VARIES
5 DON'T KNOW

C14. Do you expect to do more, or less, camping in the next 2-3 years?

1 MORE
2 LESS
3 ABOUT THE SAME
4 DON'T KNOW

(IF "MORE" OR "LESS" ON Q. C14, ASK):

C15. Why do you say that?

C16. In the past, what has kept you from camping more frequently than you have camped?

C17. During the past few years, have you noticed any major changes in the condition of campgrounds, in the costs of camping, or in the types of people who go camping? If so, what have you noticed?

C18. Approximately how much money did you spend during the past 12 months for the rental and how much for the purchases of camping equipment of all types? That is, big items like tents and trailers plus small items like sleeping bags and lanterns—but not food. First, rentals; then, purchases.

$ _____ RENTALS $ _____ PURCHASES

X NOTHING
Y DON'T KNOW

C19. Approximately how much money did you spend during the past 12 months while on camping trips in total for items like gasoline, tolls, camping fees, meals, and groceries?

$ _____

X NOTHING
Y DON'T KNOW

SHOW EXHIBIT C-1

C20. Which of these types of camping equipment have you used in the past? Please list them in the order you used them; that is, which is most like the equipment you used on your first trip, and list all others right up to that used on your last trip.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TRIP # 1. | A | B | C | D | E | F | G |
| TRIP # 2. | A | B | C | D | E | F | G |
| TRIP # 3. | A | B | C | D | E | F | G |
| TRIP # 4. | A | B | C | D | E | F | G |
| TRIP # 5. | A | B | C | D | E | F | G |
| TRIP # 6. | A | B | C | D | E | F | G |
| TRIP # 6. | A | B | C | D | E | F | G |
| TRIP # 7. | A | B | C | D | E | F | G |

INTERVIEWER: CHECK BACK TO Q. C3. IF #1 or #2 CIRCLED, ASK Q. C21 & C22; OTHERWISE, SKIP TO Q. C23.

SHOW EXHIBIT C-1

C21. Which of these types of camping equipment will you most likely use when you start camping—for your first trip?

A B C D E F G

X DON'T KNOW

C22. Will your equipment for your first trip most likely be . . .

1 Rented
2 Borrowed
3 Purchased
4 Or do you already own it?
5 DON'T KNOW

NOW SKIP TO Q. C24

C23. Which of these will you probably purchase next?

_____

X NONE OF THESE
Y DON'T KNOW

Here are some questions about your leisure time —

C24. What kinds of leisure activities (other than camping) do you participate in with members of your immediate family?

C25. What kinds of leisure activities do you and your spouse participate in, but do not share? First, your activities; then your spouse's.

Respondent's:

1. _____
2. _____
3. _____

X NONE
Y DON'T KNOW

Spouse's:

1. _____
2. _____
3. _____

X NONE
Y DON'T KNOW
Sp NO SPOUSE

C26. Approximately how many hours in an average week do you and your spouse spend in meetings and in voluntary work with clubs, civic associations, service organizations, and church activities? First, your activities, then your spouse's.

Respondents:

_____# OF HOURS

X NONE
Y DON'T KNOW

Spouse:

_____# OF HOURS

X NONE
Y DON'T KNOW
Sp NO SPOUSE

C27. What magazines are regularly received in your household?

X NONE

Y DON'T KNOW

C28. Do you belong to an automobile club?

1 YES
2 NO
3 DON'T KNOW

(IF "YES" ON Q. C28, ASK):

C29. What is the name of the automobile club(s) you belong to?

C30. At the present time, how many automobiles, vans, panel and pick-up trucks, in running condition, do you have the use of?

_____# of autos

X NONE
Y DON'T KNOW

_____# of trucks

X NONE
Y DON'T KNOW

SHOW EXHIBIT C-31

C31. During the past two years, have you visited any of the following places listed on this card? Just read me the numbers, please.

1 2 3 4 5 6

7 NONE OF THESE
8 DON'T KNOW

C32. Have you, or has anyone in your immediate family, attended a camping show, boat show, or similar exhibition of outdoor recreation equipment during the past two years?

1 YES
2 NO
3 DON'T KNOW

C33. Do you happen to recall your last 2 to 3 purchases of outdoor recreation equipment for family use, and in what year did you purchase them?

| | ITEM | YEAR PURCHASED |
|---|---|---|
| 1. | _____ ☐ | _____ ☐ |
| 2. | _____ ☐ | _____ ☐ |
| 3. | _____ ☐ | _____ ☐ |
| 4. | _____ ☐ | _____ ☐ |
| 5. | _____ ☐ | _____ ☐ |

X NONE PURCHASED
Y CAN'T REMEMBER

C34. Do you own, or have the use of a vacation home? (INTERVIEWER: INCLUDE TRAILER ONLY IF IT IS STATIONARY.)

1 YES
2 NO
3 DON'T KNOW

(IF "YES" ON Q. C34, ASK):

C35. How many miles from your home is it to your vacation home?

_____# of miles

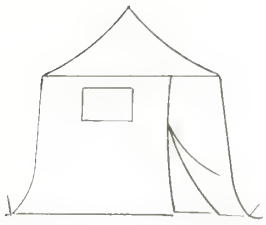
X DON'T KNOW

C36. On the average, how many days per year do you use your vacation home?

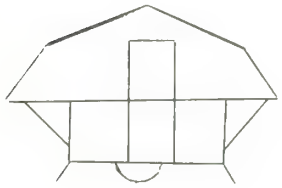
_____# of days per year

X DON'T KNOW

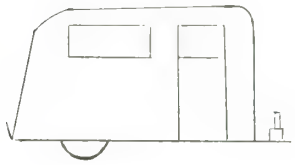
EXHIBIT C-1



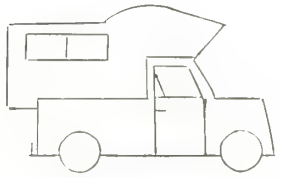
A. TENT (Any kind, any size)



B. CAMPING TRAILER (Folding)

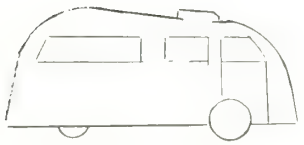


C. TRAVEL TRAILER (Any kind, any size)

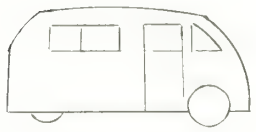


D. TRUCK CAMPER

E. PICK-UP COVER



F. MOTOR HOME



G. VAN CONVERSION

## EXHIBIT C-3

1 We are planning to try it next year.

2 We hope to try camping sometime in the future, but probably not next year.

3 We are unlikely to try camping in the foreseeable future.

4 We are definitely not interested in camping.

## EXHIBIT C-31

1 A city park or county park

2 A state park

3 A national park or recreation area

4 A national monument

5 A national forest

6 A national seashore

## SAMPLING PROCEDURES

This report presents the findings of a personal interview research survey conducted among 2,003 men and women 18 years of age or over living in private households in the continental United States.

The most advanced probability sampling techniques were used in the design and execution of the sample plan and the results, therefore, may be projected to the total U.S. population of men and women 18 years of age or over.

The Opinion Research Corporation master sample consists of 360 communities, which are arranged in six blocks. The 60 communities within each block are further distributed into six national probability samples of 10 communities each. Each block is an independent probability sample and can be used alone or in combination with other blocks.

To construct the sample, all 3070 U.S. counties were grouped into areas designated by the U.S. Office of Business Economics. Within each area, counties were arranged by descending population size. These 171 area groupings were then arranged in geographical order from north and east to south and west. Sixty counties were then chosen at random by systematic sampling (with probability proportional to size of population) to form a block. The process was repeated with different starting points to obtain a total of six blocks.

Within each county thus selected, all Minor Civil Divisions (MCD), with the estimates of their current populations, were listed. The next step was to select at random (with probability proportional to its population) a single MCD from each county.

A primary sampling unit (PSU) is a device for initiating and localizing the choice of a starting point within each county. In the Opinion Research Corporation sample, the PSU is a community, which is defined by the area covered by the largest telephone book containing the selected MCD. Sample sizes can be adjusted by varying the number of starting points within each PSU.

The sampling elements, the individuals to be interviewed, are selected as follows:

1. The required number of starting points are chosen for the PSU (telephone book), using randomizing techniques, from the households listed in each such phone book.

2. Each starting point is then used to determine a "cluster" of households (both with and without listed telephones) in which interviews will be conducted. The first interviewing point is the household immediately to the left of the starting point. Each starting point effectively determines a *neighborhood* in which interviewing will be conducted. The procedures outlined above give to every neighborhood of any given size in a stratum equal probability of being chosen for interviewing.

3. The interviewers select individuals to be interviewed from each household of the cluster by a prescribed rule. Only one interview was taken per household, regardless of the number of people 18 years of age or over in the household. Weights were introduced into the tabulations to ensure proper representation in the sample.

4. Interviewing for this Caravan survey, was completed during the period November 15 through December 6, 1971, by members of the Opinion Research Corporation national interviewing staff. All interviews were conducted in the homes of respondents.

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# *Response to*
# CROP-TREE RELEASE
## *by 7-year-old stems of Yellow-Poplar and Black Cherry*

by G. R. Trimble, Jr.

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## THE AUTHOR

G. R. TRIMBLE, JR., is timber management project leader for the Northeastern Forest Experiment Station (USDA Forest Service), at the Timber and Watershed Laboratory at Parsons, West Virginia. He received his forestry training at the University of Maine. He worked for a number of years in watershed-management research both in West Virginia and New Hampshire, and has worked on forest-management problems throughout most of the Northeastern States.

MANUSCRIPT SUBMITTED FOR PUBLICATION 1 JUNE 1972

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# Response to CROP-TREE RELEASE by 7-year-old stems of Yellow-Poplar and Black Cherry


## ABSTRACT

Five years after crop-tree release of yellow-poplar and black cherry stems in a 7-year-old stand of Appalachian hardwoods, measurements indicated that released trees were but slightly superior to control trees in height, diameter, and crown position. Sprout regrowth of cut tree stems and grapevines had largely nullified the effects of release. Indications are that for release to be effective, crop trees of these species on good sites should be 15 to 20 feet tall.


THIS is a report on the results of a crop-tree release made in a 7-year-old even-aged hardwood stand growing on an excellent site in the Central Appalachians. The objective of this study was to test the feasibility of making a crop-tree release as soon as crop trees could be selected—immediately after the canopy closed and crown classes could be distinguished.

The purpose of making the operation so early was to enhance the possibility of improving species composition. A crop-tree release was used rather than an area-wide thinning because releasing individual trees is much less expensive; and when interest rates are considered, the carrying charge for work done early in the life of a stand mounts high. To be economically justified, such work must result in an appreciable dollar improvement in the stand at harvest time.

To measure the biological response to the release operation, a number of variables were examined in detail.

The relationships established by this study add to the growing body of information about early intermediate operations in even-aged hardwood stands. More data of this nature are needed before detailed guidelines can be de-

veloped for operations of this kind—or even before a good case can be made that precommercial operations are worthwhile.

## DESCRIPTION OF THE AREA

The study locale was the Fernow Experimental Forest near Parsons, West Virginia. Site quality was excellent: site index 75 to 80 for oak. The soil was a well-drained silt loam derived mostly from sandstone and shale, but with some limestone influence. Elevation of the study area was about 2,800 feet, and steepness of slope averaged about 30 percent. Annual rainfall was about 59 inches and was well-distributed; the frost-free growing season was about 4½ months.

The 7-year-old stand developed as a result of clear-cutting a well-stocked 95-year-old unmanaged hardwood stand containing a wide variety of desirable species. The harvest produced 23,500 board feet of sawlogs and 15 cords of pulpwood per acre. All 1- to 5-inch stems left standing following this harvesting were felled shortly thereafter.

## STUDY METHODS

The sample-tree population included the two shade-intolerant species, black cherry (*Prunus serotina* Ehrh.) and yellow-poplar (*Liriodendron tulipifera* L.). For each species, three crown classes were studied: dominants, codominants, and intermediates. For each species/crown-class combination, 40 stems were designated; of these, half were chosen at random as treatment trees and half were untreated controls. Thus a total of 240 sample trees were used: 2 species x 3 crown classes x 2 treatment classes (release and control) x 20 trees per group.

These sample trees were permanently numbered and identified in the 7-year old hardwood stand. The following measurements were taken on each of them: d.b.h., height, and length of clear stem. Repeat measurements were made after two and five growing seasons. At each repeat measurement, crown classes were re-identified.

After the initial classification and measurements were made, the crop trees designated for treatment were released by cutting around the base of each in a 5-foot radius all woody stems that were over half as tall as the crop trees. All grapevines growing in the crop trees were severed. This operation left all released trees in a dominant crown position.

## RESULTS

### Effect on Height

When the data were analysed for the 5-year after-treatment period, they indicated that the height of released trees did not differ significantly from the height (at the 5-percent level) of the control stems (table 1). This was true for all three crown classes: dominant, codominant and intermediate.

However, when the data were analysed for the 2-year period and the following 3-year period separately (the 5-year period was split), a different picture emerged (figs. 1 and 2). For the 2-year period after release (7 to 9 years), released stems of all crown classes of both species grew slower than the control stems. Because we took only 2-year measurements, we do not know whether growth was reduced both years or only the first. For the following 3-year period, the situation was reversed; and released stems of all crown classes of both species grew slightly faster than control stems. Not until more time has passed will we be able to determine the duration of this trend.

This reversal of height growth advantage is consistent with the findings of Allen and Marquis (*1970*). They found that height growth was reduced by very heavy thinning and favored by moderate thinning—conditions approximated for the released crop trees during the 2-year and 3-year measurement periods after the release operation.

Two other height/growth relationships show up in the data. First is the expected greater height and greater height growth of the more dominant trees, both released and control. In addition, the data indicated that until about 10 years of age black cherry grew faster in height than yellow-poplar, but then yellow-poplar grew faster (fig. 3 and table 1).

Table 1.—Total heights and height-growth rates for released and unreleased stems

| Crown class before treatment | Treatment | Sample trees[a] | Total height[b] | | | Height growth | |
|---|---|---|---|---|---|---|---|
| | | | At 7 years | At 9 years | At 12 years | 7 to 9 years annual | 9 to 12 years annual |
| | | *No.* | *Feet* | *Feet* | *Feet* | *Feet* | *Feet* |
| | | | YELLOW-POPLAR | | | | |
| Dominant | Release | 20 | 10.55 | 14.76 | 24.51 | 2.10 | 3.25 |
| Dominant | Control | 20 | 10.22 | 15.28 | 24.01 | 2.53 | 2.91 |
| Codominant | Release | 19 | 8.84 | 12.06 | 20.66 | 1.61 | 2.87 |
| Codominant | Control | 17 | 9.03 | 13.62 | 20.48 | 2.30 | 2.29 |
| Intermediate | Release | 16 | 7.69 | 10.25 | 14.92 | 1.28 | 1.56 |
| Intermediate | Control | 14 | 8.25 | 11.57 | 14.92 | 1.66 | 1.12 |
| | | | BLACK CHERRY | | | | |
| Dominant | Release | 20 | 13.10 | 17.61 | 25.26 | 2.26 | 2.55 |
| Dominant | Control | 20 | 12.98 | 18.14 | 25.58 | 2.58 | 2.48 |
| Codominant | Release | 19 | 9.84 | 13.46 | 20.15 | 1.81 | 2.23 |
| Codominant | Control | 20 | 9.82 | 14.29 | 19.18 | 2.24 | 1.63 |
| Intermediate | Release | 19 | 7.66 | 10.22 | 15.21 | 1.28 | 1.66 |
| Intermediate | Control | 17 | 7.79 | 11.52 | 14.81 | 1.86 | 1.10 |

[a]Data are based on the trees still living at 12 years; 20 sample trees were originally designated in each class.

[b]Release and original measurements at 7 years, with succeeding measurements at 9 and 12 years.

Figure 1.—Yellow-poplar heights.

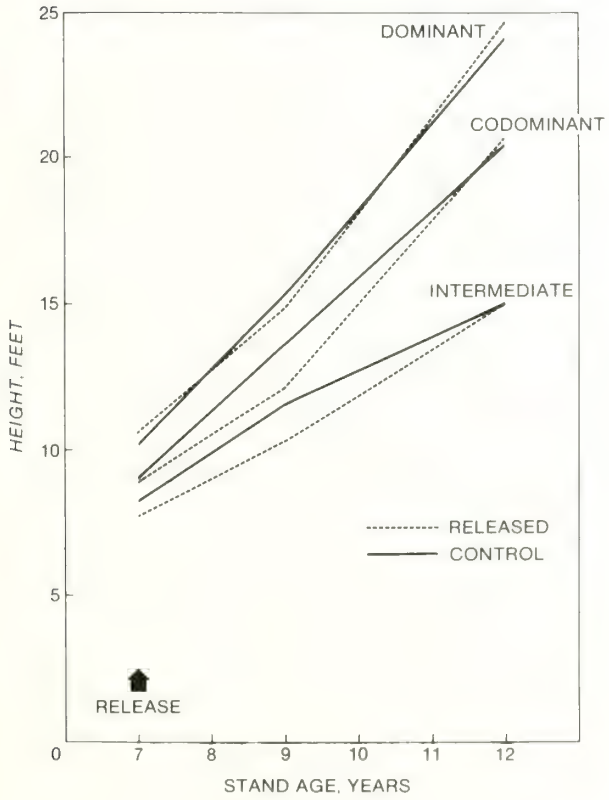


Figure 2.—Black cherry heights.

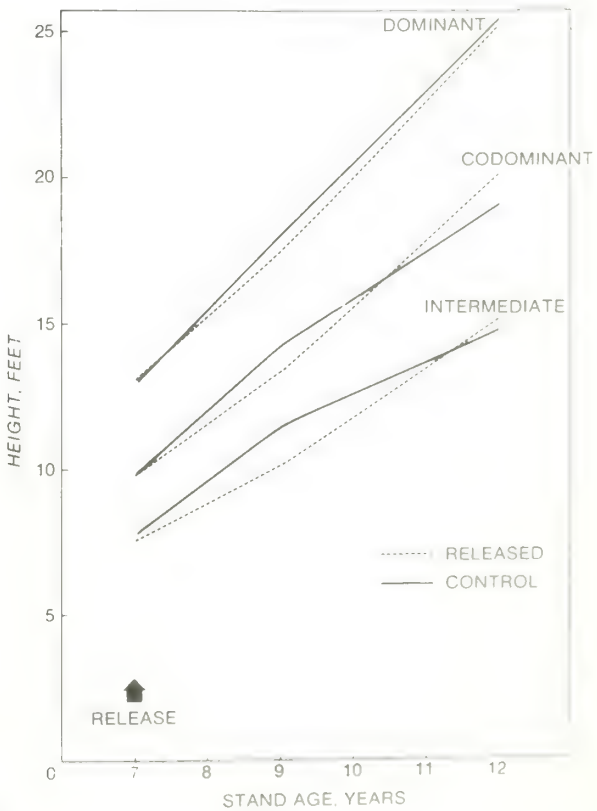

Figure 3.—Height growth of dominant unreleased stems of yellow-poplar and black cherry.

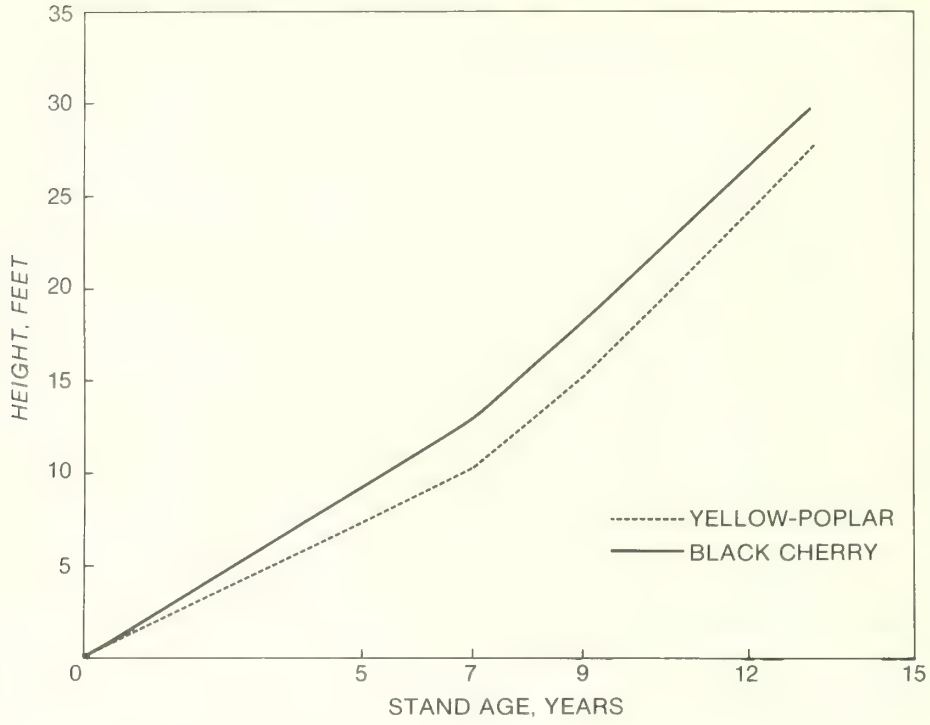


Table 2.—D.b.h. and d.b.h. growth rates for released and unreleased trees

| Crown class before treatment | Treatment | Sample trees[a] | D.b.h.[b] | | | D.b.h. growth | |
|---|---|---|---|---|---|---|---|
| | | | At 7 years | At 9 years | At 12 years | 7 to 9 years annual | 9 to 12 years annual |
| | | *No.* | *In.* | *In.* | *In.* | *In.* | *In.* |
| | | | YELLOW-POPLAR | | | | |
| Dominant | Release | 20 | 0.91 | 1.53 | 2.72 | 0.31 | 0.40 |
| Dominant | Control | 20 | .86 | 1.46 | 2.54 | .30 | .36 |
| Codominant | Release | 19 | .62 | 1.01 | 1.69 | .20 | .23 |
| Codominant | Control | 17 | .64 | 1.12 | 1.78 | .24 | .22 |
| Intermediate | Release | 16 | .47 | .72 | 1.04 | .12 | .11 |
| Intermediate | Control | 14 | .49 | .76 | 1.01 | .14 | .08 |
| | | | BLACK CHERRY | | | | |
| Dominant | Release | 20 | 1.12 | 1.79 | 2.80 | 0.34 | 0.34 |
| Dominant | Control | 20 | 1.11 | 1.80 | 2.71 | .34 | .30 |
| Codominant | Release | 19 | .64 | 1.05 | 1.56 | .20 | .17 |
| Codominant | Control | 20 | .69 | 1.06 | 1.42 | .18 | .12 |
| Intermediate | Release | 19 | .39 | .67 | .99 | .14 | .11 |
| Intermediate | Control | 17 | .40 | .62 | .77 | .11 | .05 |

[a]Data are based on the trees still living at 12 years; 20 sample trees were originally designated in each class.
[b]Release and original measurements at 7 years, with succeeding measurements at 9 and 12 years.

One reason, which at least in part accounts for the early growth superiority of black cherry, is that many of the black cherry stems were small seedling-sprouts, but all the yellow-poplars were seedlings.

## Effect on Diameter

No statistically significant difference showed up between diameter of released and control stems after 2 years and 5 years (table 2). However, for the last 3 years of the 5-year period, diameter growth was slightly greater for the released stems, particularly for the intermediate crown class where for black cherry the difference was significant at the 5-percent level. This suggests the possibilities of the same sort of delayed reaction that occurred with height growth, but to a lesser degree.

As with height growth, diameter growth was much greater for the more dominant stems, both released and unreleased. Also, as with height growth, during the measurement period yellow-poplar caught up with and surpassed black cherry in diameter growth.

## Effect on Length of Clear Stem

Release retarded stem pruning, at least temporarily. This is evidenced by the greater gain in clear length during the 2-year after-release period by the unreleased trees compared to the released trees (table 3). This relationship held for all crown classes of both species. During the succeeding 3 years, however, the released stems of all crown classes of yellow-poplar cleared up at a faster rate than control stems, indicating that for this species the two classes of trees are now approaching equality in length of clear stem. This same trend was not evident with black cherry.

No statistical difference in length of clear stem was evident between crown classes for either species, but as a *percent* of *total height*, length of clear stem increased with decreasing crown class; intermediate trees had a greater percent of stem in clear length than had dominants.

At 12 years of age, yellow-poplar had a greater percent of tree height in clear length

Table 3.—Length of clear stem and clear-stem increase for released and unreleased trees

| Crown class before treatment | Treatment | Sample trees[a] | Length of clear stem[b] | | | Clear-stem increase | |
|---|---|---|---|---|---|---|---|
| | | | At 7 years | At 9 years | At 12 years | 7 to 9 years annual | 9 to 12 years annual |
| | | *No.* | *Feet* | *Feet* | *Feet* | *Feet* | *Feet* |
| | | | YELLOW-POPLAR | | | | |
| Dominant | Release | 20 | 3.63 | 4.26 | 10.56 | 0.32 | 2.10 |
| Dominant | Control | 20 | 2.97 | 5.04 | 10.70 | 1.04 | 1.89 |
| Codominant | Release | 19 | 3.66 | 4.67 | 9.99 | .51 | 1.77 |
| Codominant | Control | 17 | 3.11 | 6.09 | 10.59 | 1.49 | 1.50 |
| Intermediate | Release | 16 | 3.76 | 4.84 | 8.17 | .54 | 1.11 |
| Intermediate | Control | 14 | 4.13 | 6.40 | 9.14 | 1.14 | .91 |
| | | | BLACK CHERRY | | | | |
| Dominant | Release | 20 | 3.50 | 3.97 | 7.50 | 0.24 | 1.18 |
| Dominant | Control | 20 | 3.49 | 4.86 | 9.34 | .68 | 1.49 |
| Codominant | Release | 19 | 3.35 | 4.11 | 7.55 | .38 | 1.15 |
| Codominant | Control | 20 | 3.86 | 4.89 | 9.88 | .52 | 1.66 |
| Intermediate | Release | 19 | 3.02 | 3.49 | 6.64 | .24 | 1.05 |
| Intermediate | Control | 17 | 3.66 | 4.85 | 6.88 | .60 | .68 |

[a]Data are based on the trees still living at 12 years; 20 sample trees were originally designated in each class.

[b]Release and original measurements at 7 years, with succeeding measurements at 9 and 12 years.

than had black cherry, for both release and control trees. Yellow-poplar is obviously a faster pruner.

## Effect on Dominance Classification

As stated previously, crown classes were determined before release, but all released trees were left after the operation in a dominant position. The control (unreleased) trees were left in their original crown position. At 5 years, all sample trees were again classified as to crown position (table 4). The changes over this 5-year period lead to the following statements:

For both species, many trees of all crown classes, both released and control, retrogressed. This was true even of dominant trees; only 60 percent of released dominant yellow-poplar and black cherry were still dominant 5 years after release. The percentages for control dominants were about the same—50 percent of the yellow-poplar and 60 percent of the black cherry stems were still dominant after 5 years. In the 12-year-old stand, 80 to 95 percent of all originally dominant stems were codominant or better.

About 50 percent of the yellow-poplar codominant (original crown positions) were codominant or better after 5 years, with little difference between released and control stems. For codominant black cherry, the figure was about 25 percent, with little difference between released and control stems.

Intermediate trees of both species, both release and control stems, were retrogressing rapidly at 12 years, although current figures indicate that release has retarded this somewhat (table 4). Five to 15 percent of the originally intermediate stems were codominant or better at 5 years.

In general, after 5 years the effects of release on crown position were small and were limited largely to the intermediate crown class which, however, showed no promise of becoming a permanent component of the stand.

Assuming a codominant position as the minimum dominance level acceptable for a potential crop tree in the 12-year-old stand, it appears then that in the 7-year-old stand only dominant trees are good prospects of being codominant or better 5 years later. And because release apparently results in little growth improvement in trees of this crown class, there is little or nothing to be gained by releasing them.

Table 4.—Five-year change in crown class

| Crown class before release in 1966 | Treatment | Crown class 5 years later | | | | | | | | Dead | | Dead and overtopped |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dominant | | Codominant | | Intermediate | | Overtopped | | | | |
| | | *No.* | *Pct.* | *No.* | *Pct.* | *No.* | *Pct.* | *No.* | *Pct.* | *No.* | *Pct.* | *Pct.* |
| | | | | | | YELLOW-POPLAR | | | | | | |
| Dominant | Release | 12 | 60 | 6 | 30 | 2 | 10 | 0 | 0 | 0 | 0 | 0 |
| Dominant | Control | 10 | 50 | 6 | 30 | 3 | 15 | 1 | 5 | 0 | 0 | 5 |
| Codominant | Release | 1 | 5 | 9 | 45 | 7 | 35 | 2 | 10 | 1 | 5 | 15 |
| Codominant | Control | 4 | 20 | 7 | 35 | 4 | 20 | 2 | 10 | 3 | 15 | 25 |
| Intermediate | Release | 0 | 0 | 2 | 10 | 7 | 35 | 7 | 35 | 4 | 20 | 55 |
| Intermediate | Control | 0 | 0 | 1 | 5 | 3 | 15 | 10 | 50 | 6 | 30 | 80 |
| | | | | | | BLACK CHERRY | | | | | | |
| Dominant | Release | 12 | 60 | 7 | 35 | 0 | 0 | 1 | 5 | 0 | 0 | 5 |
| Dominant | Control | 12 | 60 | 5 | 25 | 3 | 15 | 0 | 0 | 0 | 0 | 0 |
| Codominant | Release | 2 | 10 | 2 | 10 | 10 | 50 | 5 | 25 | 1 | 5 | 30 |
| Codominant | Control | 1 | 5 | 4 | 20 | 10 | 50 | 5 | 25 | 0 | 0 | 25 |
| Intermediate | Release | 0 | 0 | 3 | 15 | 6 | 30 | 10 | 50 | 1 | 5 | 55 |
| Intermediate | Control | 0 | 0 | 1 | 5 | 1 | 5 | 15 | 75 | 3 | 15 | 90 |

The 5-year after-release crown-class distribution has several important implications:

1. The lack of consistency from the 7- to 12-year measurement in crown classification of the dominant and codominant controls indicates that at 7 years of age crown position was neither well defined nor stabilized.

2. The rapid overtopping of released intermediates, and to a lesser extent codominants, indicates strongly that many released trees were too short (too young) to stay ahead of the rapid regrowth of sprouts from stems cut in the release operation. We measured a number of such sprouts that had grown over 20 feet in 5 years.

3. Because the effects of release in improving crown position were small and were limited largely to the originally intermediate stems (which are mostly on their way out of the stand), indications are that from now on the released trees will show little or no growth or survival advantages.

The results of this study are somewhat different from the results of a study made on the Pisgah National Forest in North Carolina in 1924. That cleaning, made in an 8-year-old stand, resulted in an improvement in species composition of the upper canopy level that has persisted for 26 years (*Wahlenberg 1950*). Presumably many of the stems released in cleaning were tall enough to stay ahead of sprout regrowth, or perhaps there were other now unassessable differences between the two studies that render invalid comparisons of results.

## Effect on Mortality

Five years after the study was begun (when the stand was 12 years old), the intermediate control stems (7-year designation) were dying; 30 percent of the yellow-poplar and 15 percent of the black cherry had already succumbed (table 4), and many trees of both species were barely alive. The release stems of this crown class were dying also but at a slower rate.

Of the stems originally designated codominant, three control trees and two released trees were dead.

All the originally dominant stems of both species were still alive.

Nineteen stems out of a total 240 had died by the time the stand was 12 years old—7 release stems and 12 control stems. Seventeen of these appeared to have succumbed to competition of other woody stems; two appeared to have been killed by grapevines.

Mortality had been somewhat higher among yellow-poplar stems than among black cherry.

## Effect on Grapevines

Grapevines do serious damage in hardwood stands on good and excellent sites in the Appalachians. This is particularly true in young even-aged stands where the intolerant vines sprout profusely after the old stand is harvested. Sprouts from cut-off vines grow 5 to 15 feet in length the first growing season after a clearcutting. Mounting in the crowns of young trees, these vines break off limbs and tops, twist and bend over the main stem, augment ice and snow damage, and submerge the tree foliage in large grape leaves and thus interfere with photosynthesis.

The presence of grapevines in sample trees was recorded 5 years after treatment. Three categories of grapevine occurrence were recorded: no grapevine present, grapevine present, and grapevine damage severe (this was a subjective appraisal). Unfortunately, although grapevines were cut out of release trees in the 7-year-old stand, their presence was not recorded at the time for either the release or the control stems.

Five years after the release operation, about two-thirds of the sample trees had grapevines in their crowns (table 5). The situation was the same for both release and control stems, indicating that in most cases the vines had regrown into the release trees after their elimination 5 years previously. Severe grapevine damage was recorded for about ¼ of all sample trees, with a slightly higher incidence for the control stems—from which the grapevines had not been temporarily removed.

With such a high incidence of severe grapevine damage, it would seem that both height and diameter growth would be affected; and

Table 5.—Stems with grapevines

| Crown class before release in 1966 | Treatment | Stems with grapevines | | Stems with severe grapevine damage | |
|---|---|---|---|---|---|
| | | *No.* | *Pct.* | *No.* | *Pct.* |
| YELLOW-POPLAR | | | | | |
| Dominant | Release | 15 | 75 | 5 | 25 |
| Dominant | Control | 16 | 80 | 6 | 30 |
| Codominant | Release | 14 | 74 | 4 | 21 |
| Codominant | Control | 14 | 82 | 5 | 29 |
| Intermediate | Release | 8 | 50 | 2 | 12 |
| Intermediate | Control | 7 | 50 | 7 | 50 |
| BLACK CHERRY | | | | | |
| Dominant | Release | 11 | 55 | 4 | 20 |
| Dominant | Control | 11 | 55 | 3 | 15 |
| Codominant | Release | 18 | 95 | 6 | 32 |
| Codominant | Control | 17 | 85 | 8 | 40 |
| Intermediate | Release | 11 | 58 | 3 | 16 |
| Intermediate | Control | 4 | 24 | 0 | 0 |
| Average: | | | | | |
| All live stems | | 146 | 66 | 53 | 24 |
| Release stems | | 77 | 68 | 24 | 21 |
| Control stems | | 69 | 64 | 29 | 27 |

an attempt was made to determine if this were in fact the case. For each class of trees—species crown-class treatment group—5-year height growth and d.b.h. data were compiled separately for trees with and without severe grapevine damage. There were 11 such groups of trees (there would have been 12, but one class had no stems with severe grapevine damage so no comparison was possible). Eight of the 11 groups had greater growth rates—both height and d.b.h.—for the stems without severe grapevine damage (table 6), indicating that this damage adversely affects growth.

In view of the high incidence of grapevines in crop trees—66 percent—we can probably anticipate that a greater proportion of crop trees will suffer severe damage in this stand in the future.

## CONCLUSIONS AND DISCUSSION

The analyses made of the biological response of crop trees to release fulfills the primary objective of this research: to determine whether a long-lasting stand improvement will result from a crop-tree release made in a young hardwood stand as soon as the canopy closes and crown classes can be distinguished.

Based on the 5-year study period, indications are that, for yellow-poplar and black cherry on sites like the study site, release at 7 years is too early to permanently improve the crown position of most of the released trees. Because we cannot effect a lasting improvement in crown position, we cannot expect to

Table 6.—Effect of severe grapevine damage on 5-year after-release growth

| Dominance class | Treatment | Number of trees | | Height growth | | | | D.b.h. growth | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | With severe damage | Without severe damage | With severe damage | Without severe damage | Sign. of diff. | Damaged trees + or − growth | With severe damage | Without severe damage | Sign. of diff. | Damaged trees + or − growth |
| | | *No.* | *No.* | *Feet* | *Feet* | | | *Inches* | *Inches* | | |
| | | | | | YELLOW-POPLAR | | | | | | |
| Dominant | Release | 5 | 15 | 11.56 | 14.13 | * | − | 1.620 | 1.875 | NS | − |
| Dominant | Control | 6 | 14 | 10.38 | 15.24 | * | − | 1.367 | 1.864 | NS | − |
| Codominant | Release | 4 | 15 | 9.58 | 12.42 | NS | − | .900 | 1.120 | NS | − |
| Codominant | Control | 5 | 12 | 8.04 | 12.87 | * | − | .940 | 1.217 | NS | − |
| Intermediate | Release | 2 | 14 | 4.35 | 7.65 | NS | − | .250 | .607 | NS | − |
| Intermediate | Control | 2 | 12 | 8.75 | 6.32 | NS | + | .700 | .492 | NS | + |
| | | | | | BLACK CHERRY | | | | | | |
| Dominant | Release | 4 | 16 | 8.30 | 13.12 | * | − | 0.975 | 1.856 | * | − |
| Dominant | Control | 3 | 17 | 14.15 | 12.33 | NS | + | 1.633 | 1.600 | NS | + |
| Codominant | Release | 6 | 13 | 10.25 | 10.34 | NS | − | .833 | .954 | NS | − |
| Codominant | Control | 8 | 12 | 7.36 | 10.69 | * | − | .675 | .775 | NS | − |
| Intermediate | Release | 3 | 16 | 9.63 | 7.16 | NS | + | .933 | .544 | * | + |
| Intermediate | Control | 0 | — | — | — | — | — | — | — | — | — |

*Significant at the 5-percent level.

improve species composition or to effect much of a growth increase.

To produce permanent improvement in stands this young would require that the release operations be repeated in a few years, and this would be costly. A better alternative would be to postpone the operation until such a time as the crown classes are more stable and the potential for damage from regrowth of cut grapevines and from sprouts of tree stems cut in the release operation has substantially diminished.

In a previous report about the cost and methodology phases of this study (*Trimble 1971*), a recommendation was made that crop-tree release be postponed until the stand was 9 to 12 years old. If we wait until then, the potential release trees will be taller; and the results of previous research show that thinning in stands of this size brings about stand improvement that persists (*Stoeckler and Arbogast 1947, Conover and Ralston 1959, Drinkwater 1960, and Della-Bianca 1969*).

At this stage, we recommend that, if a crop-tree release is made, it be postponed until crop trees are at least 15 feet tall; and in stands with a high incidence of grapevines, it would be wise to wait until the trees are 25 feet tall.

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by Roger E. McCay
and Paul S. DeBald

# A PROBABILITY APPROACH TO SAWTIMBER TREE-VALUE PROJECTIONS

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## THE AUTHORS

ROGER E. McCAY received his bachelor of science degree in forest management from Iowa State University in 1966 and his master's degree in agricultural economics from the Ohio State University in 1970. He joined the USDA Forest Service's Northeastern Forest Experiment Station survey project for Ohio in 1966. In 1967 he transferred to the forest economics project located in Columbus, Ohio.

PAUL S. DeBALD is a research forester with the Northeastern Forest Experiment Station's economics project in Columbus, Ohio. A graduate of the Pennsylvania State University, he began his Forest Service career in 1959. Before taking his present assignment, Paul served on the forest survey staffs of the Lake States and Central States Stations, being associated with the surveys of several Midwestern States. At present he is specializing in forest tree and stand evaluations.

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# A PROBABILITY APPROACH TO SAWTIMBER TREE-VALUE PROJECTIONS


## ABSTRACT

The authors present a method for projecting hardwood sawtimber tree values, using tree-development probabilities based on continuous forest inventory (CFI) data and describe some ways to use the resulting value projections to assemble management-planning information.


TIMBER VALUATION is an important part of a forestry business. A timber owner who knows what his trees are worth right now and has a pretty good idea of what they could be worth at the end of some time period can plan his forest management during that period to best meet his financial objectives.

Assigning current values to trees or stands is usually relatively easy. Projecting tree values is a lot harder, especially for hardwood sawtimber, because each sawtimber tree's value is related to its size and quality. And the tree's projected value depends on how it changes in both size and quality.

For any given tree, a wide range of possibilities exists, in both size and quality change and resultant tree value. Probability projection will allow us to cover the entire range of possible tree changes that might be expected, rather than just the average changes. And it will allow us to estimate the likelihood of attaining projected values.

We describe here a method for projecting sawtimber tree values, using tree-development probabilities based on continuous forest inventory (CFI) data for a specific forest. We also describe some ways to use the resulting value projections to assemble management-planning information for a forest. Our aim is to project future values for existing sawtimber trees, and not to project stand tables or yield tables. Thus we will simplify the description of our method by dismissing ingrowth and mortality.

Neither the projections nor their applications are intended to be general guides. Our

purpose is to give forest owners a method that they can use to develop comparable management information for their own tracts.

## PROBABILITY PRINCIPLES

We can observe an occurrence a large number of times and find the relative frequency with which the various outcomes occur. For example, suppose we measured the diameters of 200 16-inch black oak trees on a series of randomly selected sample plots, then remeasured the same trees 5 years later. Suppose, further, that we found that 120 trees grew 0.5 inch during the 5-year period, 60 trees grew 0.8 inch, and 20 grew 1.0 inch. The relative frequencies of the various growth levels would be:

| *Diameter change (inch)* | *Frequency (number of trees)* | *Relative frequency of occurrence* |
|---|---|---|
| 0.5 | 120 | 120/200 = .60 |
| .8 | 60 | 60/200 = .30 |
| 1.0 | 20 | 20/200 = .10 |
| | 200 | 1.00 |

We could use these relative frequencies to estimate growth probabilities for the rest of the 16-inch black oaks in our forest.

We could use the same approach to estimate the probabilities for changes in merchantable height and tree quality. Then, by combining the probabilities for all three variables, we could estimate the probabilities of trees developing in a combination of ways.

## OBSERVED PROBABILITIES

The data used in this study were obtained from more than 400 randomly selected plots, maintained by the Muskingum Watershed Conservancy District in Ohio. The plots were established in 1955 and remeasured twice—in 1960 and in 1965. The data used came from the 1955 and 1965 remeasurements. We chose the 10-year period because 10 years is commonly used in management planning. It allows for annual fluctuations in precipitation and length of growing season. Thus the changes in diameter, merchantable height, and tree quality are based on 10 years of tree development.

### Diameter Changes

Diameters breast high (d.b.h.) had been measured to the nearest 1/10 inch with a diameter tape. The actual diameter changes were found by subtracting a tree's 1955 diameter from its 1965 diameter. But, for simplicity in illustrating our method, we combined the diameter changes into 1-inch classes.

Finding a lot of variation in growth rates from one species to another, we grouped the species into fast, medium, and slow growers. The fast growers included yellow-poplar, red oak, black oak, and soft maple. Medium growers included white ash, hard maple, and American elm. Slow growers included white oak, beech, black cherry, and hickory.

We then sorted the trees in each group into 2-inch diameter classes and, in each diameter class, found the percentage of trees changing by 1-inch growth classes. These percentages, or relative frequencies, indicate the probabilities of attaining given levels of 10-year diameter growth (table 1). For example, we can expect 46 percent of the 14-inch fast growers on the forest to grow 2 inches in 10 years.

We ignored the possible implications of

Table 1.—*Probabilities of trees attaining given levels of diameter growth, by diameter class*

[In percent]

| Diameter class (inches) | Number of trees | 10-year diameter growth in inches: <1 | 1 | 2 | 3 | 3+ |
|---|---|---|---|---|---|---|
| FAST GROWING TREES | | | | | | |
| *Yellow-poplar, red oak, black oak, and soft maple* | | | | | | |
| 12 | 42 | 5 | 31 | 35 | 22 | 7 |
| 14 | 26 | 4 | 27 | 46 | 12 | 11 |
| 16 | 22 | 4 | 19 | 27 | 32 | 18 |
| 18 | 14 | — | 7 | 57 | 36 | — |
| 20+ | 30 | 7 | 10 | 57 | 23 | 3 |
| MEDIUM GROWING TREES | | | | | | |
| *White ash, hard maple, and American elm* | | | | | | |
| 12 | 38 | 3 | 34 | 42 | 16 | 5 |
| 14 | 22 | 9 | 36 | 37 | 13 | 5 |
| 16 | 17 | 12 | 35 | 29 | 18 | 6 |
| 18 | 5 | — | 80 | 20 | — | — |
| 20+ | 6 | — | — | 66 | 17 | 17 |
| SLOW GROWING TREES | | | | | | |
| *White oak, beech, black cherry, and hickory* | | | | | | |
| 12 | 92 | 17 | 42 | 34 | 7 | — |
| 14 | 54 | 15 | 40 | 30 | 13 | 2 |
| 16 | 47 | 6 | 43 | 45 | 6 | — |
| 18 | 12 | 17 | 25 | 50 | 8 | — |
| 20+ | 26 | 4 | 38 | 43 | 15 | — |

stocking level or stand density on individual tree diameter growth. For simplicity, we have assumed constant stand competition. However, the effect of changing stand density should be considered in practical applications.

### Merchantable-Height Changes

In each of the CFI tallies every sawtimber tree was assigned a merchantable height for sawlogs. These were estimated to the nearest 2 feet, and the estimates were spot-checked with a clinometer.

(A sawlog is a log that is at least 8 feet long, has a minimum top diameter of 8 inches inside bark, and meets minimum timber-grading specifications for hardwood factory-lumber logs or construction logs, as defined in USDA Forest Products Laboratory studies.)

We found the 10-year height change for each tree. But, because the height changes were not significantly different from one species to another, we did not stratify the trees into species groups. Instead, we sorted all the trees into four height-change classes: those that did not change in height; those that increased less than a half log; those that increased at least a half log but less than one 16-foot log; and those that increased by one or more 16-foot logs.

The relative frequencies of height changes (table 2) show that more than half of the trees failed to increase in height at all and that we can expect less than 10 percent of them to add a log or more in 10 years (less than 1 percent increased a log and half).

Table 2.—*Probabilities of changes in sawlog height, by diameter class*

[In percent]

| Diameter class (inches) | Number of trees | 10-year change in sawlog height (16-ft. logs) | | | |
|---|---|---|---|---|---|
| | | No change | Less than ½ log | ½ log to 1 log | 1 log or more |
| 12 | 172 | 52 | 27 | 17 | 4 |
| 14 | 102 | 66 | 12 | 17 | 5 |
| 16 | 86 | 57 | 19 | 17 | 7 |
| 18 | 31 | 70 | 18 | 9 | 3 |
| 20+ | 62 | 66 | 20 | 11 | 3 |

### Tree-Quality Changes

Five quality classes were tallied for sawtimber trees on the plots: log grades 1, 2, and 3, tie and structural grade, and cull. These classes were based primarily on standards developed by the USDA Forest Service (*Ostrander 1965*). They were assigned according to butt-log quality. Trees less than 50 percent sound were classed as cull.

We used a slightly different method for estimating probabilities of changes in tree quality. First we sorted the trees in each diameter class into initial (1955) quality classes. Next we sorted the trees in each initial quality class into ending (1965) quality classes. Then we found the proportion of the initial class that the trees in each ending class represented (table 3).

Table 3.—*Calculating the probability of quality changes in 14-inch grade-3 trees*

| Tree-quality class | | Number of trees | Percent |
|---|---|---|---|
| Initial | Ending | | |
| Grade 3 | Cull | 1 | 3 |
| | Tie & structural (T&S) | 1 | 3 |
| | Grade 3 | 25 | 65 |
| | Grade 2 | 8 | 21 |
| | Grade 1 | 3 | 8 |
| | Total | 38 | 100 |

Probability trees provide a convenient way to display tree-quality changes (fig. 1 and fig. 2). These show, for each diameter class, the number of trees by initial quality class, and the percentage of those trees in each ending quality class.

As we expected, few trees improved in quality during the 10-year period. Quality improvement is a relatively slow process. On the other hand, we did find some trees that dropped in quality class, because of weather damage or increased defect. Such changes, though infrequent, usually occur quickly.

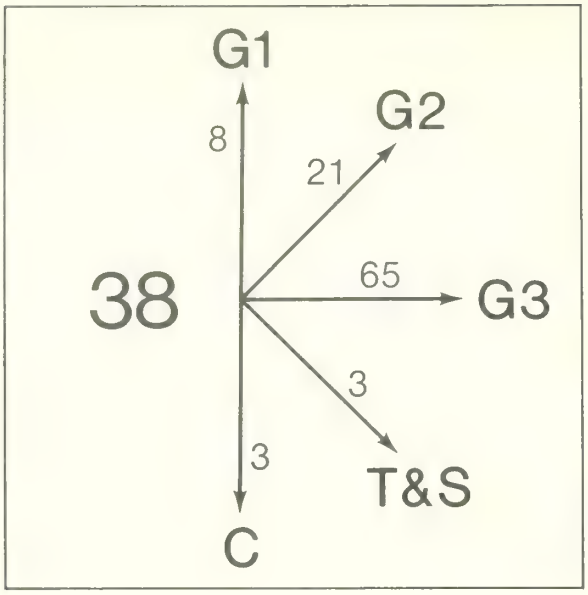



Figure 1.—A sample probability tree, for quality changes in 14-inch grade-3 trees.

The large figure at the left shows number of trees. The figures on the arrows show the percentage of trees moving into the final quality classes.

Probability trees for all five grades and diameter classes are shown in Figure 2.

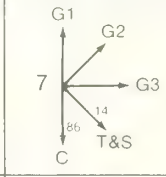
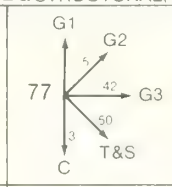
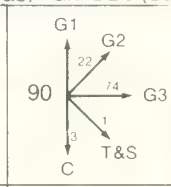
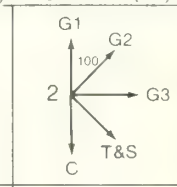
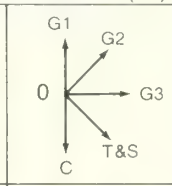
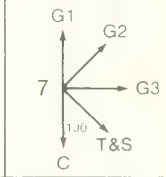
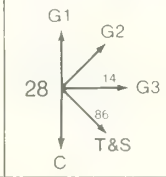
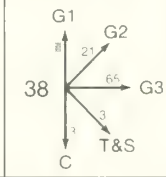
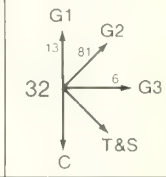
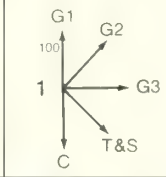
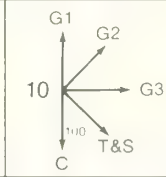
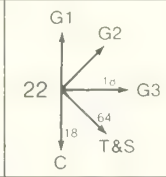
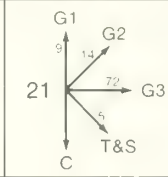
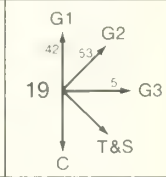
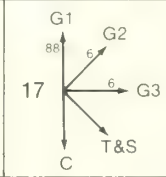
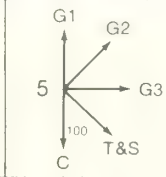
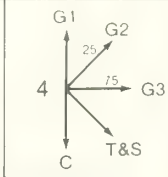
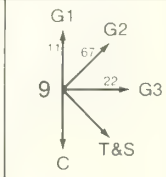
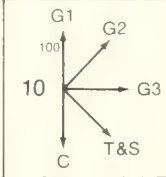
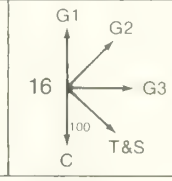
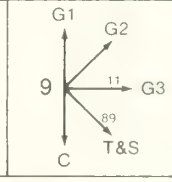
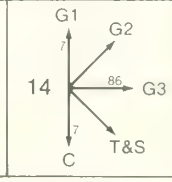
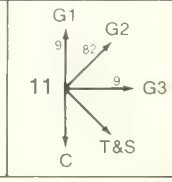
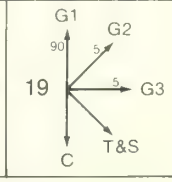
| DIAMETER CLASS | INITIAL QUALITY CLASS | | | | |
|---|---|---|---|---|---|
| | CULL (C) | TIE & STRUCTURAL(T&S) | GRADE 3 (G3) | GRADE 2 (G2) | GRADE 1 (G1) |
| 12 |  |  |  |  |  |
| 14 |  |  |  |  |  |
| 16 |  |  |  |  |  |
| 18 |  | |  |  |  |
| 20+ |  |  |  |  |  |

Figure 2.—Probabilities of 10-year quality changes, for five diameter classes and five quality classes.

## COMBINED PROBABILITIES

We can combine the probabilities of changes in diameter, merchantable height, and tree quality by multiplying them. In doing so we would be treating the changes as independent occurrences. (Chi-square tests failed to demonstrate any real association between diameter growth and merchantable height growth, except for 12-inch trees. Similar tests failed to demonstrate any real association between diameter growth and tree quality changes, regardless of tree size.) These combined probabilities indicate the likelihood with which a given tree can develop in a combination of ways.

Take an 18-inch 2-log red oak with a butt-log grade of 2, for example. What is the probability of its growing 1, 2, or 3 inches in diameter? Of increasing in sawlog height by another 16-foot log? Or of changing in quality? With what probabilities can we expect various combinations of these changes to occur?

Table 4 has been prepared to show how value projections can be made for an 18-inch, 2-log, grade-2 red oak. Columns 4, 5, and 6 show the results of the changes—all the possible combinations of resultant trees. The probabilities of these changes are shown in columns 7, 8, and 9.

The combined probabilities for each set of possible changes—or for the tree that would result from those changes—are shown in column 10. The probability of each combination is the product of the probabilities of changes in diameter, height, and quality that would result in that combination. For example, the probability of our 18-inch tree growing 2 inches is 0.57; the probability of its merchantable height remaining at two logs is 0.97; the probability of its staying grade 2 is 0.67. Thus the combined probability of our 18-inch, 2-log, grade-2 tree becoming a 20-inch, 2-log, grade-2 tree is 0.57 x 0.97 x 0.67 or 0.370.

We should mention at this point that our method is a transition matrix approach to tree-development estimation. Many excellent texts discuss transition probability theory (*Miller and Starr 1960; Howard 1960*). But, again for simplicity, we chose to avoid direct use of matrix manipulations and mathematical notations.

However, we must point out that in theory a matrix of transition probabilities is assumed to remain constant through time. In reality, transition probabilities might not remain constant. They might change as surrounding conditions in the real world change (*Burford 1966*). This is likely to be the case with most forest land, as the stands progress toward

Table 4.—*Value projections for an 18-inch, 2-log, grade-2 red oak*

| Probability table | | | | | | | | | | | Evaluation table | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial tree variables | | | Ending tree variables | | | Probability of attaining ending tree variables | | | Probability of attaining all variables, | Trees w/ending characteristics, | Initial value of trees ($) | | Ending value of trees ($) | | Value change ($) | | Rate of value increase per tree, |
| D.b.h., *in.* | Ht., *ft.* | Quality | D.b.h., *in.* | Ht., *ft.* | Quality | D.b.h., *pct.* | Ht., *pct.* | Quality | *pct.* | *No.* | Per tree | Total | Per tree | Total | Per tree | Total | *pct.* |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) |
| 18.0 | 32 | 2 | 19.0 | 32 | 3 | 0.07 | 0.97 | 0.22 | 0.015 | 6 | 2.82 | 16.92 | −2.35 | −14.10 | −5.17 | −31.02 | 0 |
| | | | | | 2 | .07 | .97 | .67 | .045 | 18 | | 50.76 | 4.21 | 75.78 | 1.39 | 25.02 | 4.1 |
| | | | | | 1 | .07 | .97 | .11 | .007 | 3 | | 8.46 | 10.22 | 30.66 | 7.40 | 22.20 | 13.7 |
| | | | | 48 | 3 | .07 | .03 | .22 | .000 | 0 | | — | — | — | — | — | — |
| | | | | | 2 | .07 | .03 | .67 | .001 | 0 | | — | — | — | — | — | — |
| | | | | | 1 | .07 | .03 | .11 | .000 | 0 | | — | — | — | — | — | — |
| | | | 20.0 | 32 | 3 | .57 | .97 | .22 | .122 | 49 | | 138.18 | −1.86 | −91.14 | −4.68 | −229.32 | 0 |
| | | | | | 2 | .57 | .97 | .67 | .370 | 148 | | 417.36 | 5.89 | 871.72 | 3.07 | 454.36 | 7.6 |
| | | | | | 1 | .57 | .97 | .11 | .061 | 24 | | 67.68 | 13.13 | 315.12 | 10.31 | 247.44 | 16.6 |
| | | | | 48 | 3 | .57 | .03 | .22 | .004 | 2 | | 5.64 | −3.41 | −6.82 | −6.23 | −12.46 | 0 |
| | | | | | 2 | .57 | .03 | .67 | .012 | 5 | | 14.10 | 5.87 | 29.35 | 3.05 | 15.25 | 7.6 |
| | | | | | 1 | .57 | .03 | .11 | .002 | 1 | | 2.82 | 14.00 | 14.00 | 11.18 | 11.18 | 17.4 |
| | | | 21.0 | 32 | 3 | .36 | .97 | .22 | .077 | 31 | | 87.42 | −1.21 | −37.51 | −4.03 | −124.93 | 0 |
| | | | | | 2 | .36 | .97 | .67 | .234 | 94 | | 265.08 | 7.84 | 736.96 | 5.02 | 471.88 | 10.8 |
| | | | | | 1 | .36 | .97 | .11 | .038 | 15 | | 42.30 | 16.41 | 246.15 | 13.59 | 203.85 | 19.2 |
| | | | | 48 | 3 | .36 | .03 | .22 | .002 | 1 | | 2.82 | −2.61 | −2.61 | −5.43 | −5.43 | 0 |
| | | | | | 2 | .36 | .03 | .67 | .007 | 3 | | 8.46 | 8.26 | 24.78 | 5.44 | 16.32 | 11.3 |
| | | | | | 1 | .36 | .03 | .11 | .001 | 0 | | — | — | — | | | |
| | | | | | | | | | | | | 1,128.00 | | 2,192.34 | | 1,064.34 | 6.9 |

maturity. So we must caution that our method for projecting sawtimber tree values should not be used for long-range projections. Rather, it should be used for more immediate planning periods, such as we have done for a 10-year management period in the following discussion.

## APPLYING COMBINED PROBABILITIES

### Projected Future Trees

From the combined probabilities, we can estimate the likelihood of each of the ways we might expect our initial tree to develop. We can also use them to project the future trees that would result from changes.

Say our sample has an expansion factor of 400, and our initial tree represents 400 similar trees on the forest property. We can proportion those 400 trees according to our combined probabilities and estimate the future number of trees with each combination of ending characteristics (table 4, column 11). This gives us a future tree distribution based on expected changes in the 400 trees represented by our initial tree.

### Projected-Value Tables

We can now assign values to our initial and future trees. The tree values used here represent a tree's net worth when converted to 4/4 inch lumber, based on average lumber prices for 1962-67 and including conversion costs (*Trimble and Mendel 1969*). The original 400 trees are valued at $2.82 each (table 4, column 12). But the future tree values vary considerably, from −$3.41 to $16.41. The average is $5.31 (table 4, column 14). The trees with negative values are those that would cost more to convert into lumber than the lumber would be worth.

To compute initial and future values for our 400 trees, we need only to multiply individual tree values (column 12 and 14) by the future tree distribution (column 11). The results of these computations (columns 13 and 15) show that we can expect the original trees to nearly double in value in 10 years.

The changes in value (columns 16 and 17) are simply the differences between future and initial values. Note the wide range in value changes for individual trees. This emphasizes the variation in tree earning power and reflects the many different returns that are possible from trees developing in different ways. The total value change (column 17) indicates the overall accrual in net value that we can expect from the 18-inch, 2-log, grade-2 red oaks on our forest property.

The rate-of-value-increase figures (column 18) were computed by solving for p in the compound-interest formula

$$V_n = V_o (1 + p)^n$$

where $V_n$ = future tree value, $V_o$ = initial tree value, and n = 10 years. Here, too, we find a big spread resulting from the various tree-development possibilities.

## MANAGEMENT PLANNING INFORMATION

Up to this point we have generated a good deal of biological and economic data—but all for one tree. The thought of repeating the operation for the rest of the trees in your forest may seem appalling. With the widespread availability of computer services, it need not be. Even hand computations, such as we have made, are really not that laborious when considered in terms of the management-planning information they can be used to develop.

Our 18-inch example tree can be used to point out some types of planning information that we can derive after projecting values for our entire stand. First, we would know the present value of our trees and have a pretty good idea of their future value. In this case we could expect our grade-2, 18-inch red oaks to nearly double in value. In doing so they would be increasing in value at an annual rate of 6.9 percent.

After generating comparable data for the rest of our forest we could aggregate them to find the present and future timber value, the expected change in timber value, and the rate of that change for the entire forest. Information of this sort would give the forest owner a set of value measures that he could use to compare his forest's development against his short-term financial objectives. Such informa-

tion also would provide him with sideboards for deciding on the levels of management he should consider. It also would give him a yardstick for comparing the benefits from the various management alternatives he might be considering.

We could also aggregate the tree-value measures by species or species groups. We could then compare the economic performance of one species against another. Or we could compare species performance against the owner's economic objectives. Such comparisons could serve as a basis for earmarking desirable or undesirable species and could be worked into silvicultural guides.

We could also use projected tree values to analyze tree development. For an example look closer at the value projections for our 18-inch red oak, and observe some of its development patterns.

### Diameter Growth

Most of our value is in trees that we expect will grow 2 inches, but most of our value increase will be in those trees that grow 3 inches in diameter:

| *Diameter change (inches)* | *Trees (no.)* | *Initial value* | *Future value* | *Value change* | *Average value change* | *Rate of value increase (percent)* |
|---|---|---|---|---|---|---|
| 1 | 27 | $76.14 | $92.34 | $16.20 | $0.60 | 1.9 |
| 2 | 229 | 645.78 | 1,132.23 | 486.45 | 2.12 | 5.8 |
| 3 | 144 | 406.08 | 967.77 | 561.69 | 3.90 | 9.1 |

The average value increase for a tree that grows 3 inches is nearly double the increase of one that grows only 2 inches. The differences in the rates of value increase are equally striking. We see, too, that our 1-inch growers are not adding much to our forest business. But fortunately we have few of them.

Application of this information depends, of course, on the forest owner's economic objectives. Given those objectives, we could use our value projections to develop management policies based on diameter growth expectations. These, in turn, could be related to tree-vigor classifications that reflect a tree's diameter growth potential and could be incorporated into general cutting guides.

If, for example, the forest owner wanted to build up his capital in growing timber, he would generally favor the 2- and 3-inch growers and eliminate the 1-inch growers, giving more growing space to his faster growing, faster earning trees. The same policy would also satisfy an objective of eliminating those trees whose rate of value increase averages less than 2 percent. But only the fastest growing 18-inch red oaks will, on the average, meet an objective of earning at the rate of 8 percent or higher.

Basing value projections on tree-development probabilities tells us more than which kinds of trees we can expect to meet or fail to meet various economic criteria. It tells us how many. This added information is often useful in scheduling cutting budgets for a forest holding.

Thus the forest owner might well be satisfied with incorporating diameter growth expectations into a general cutting-guide policy. However, he might want to build an exception or two into his general rule. After all, some of the slow growers may meet his financial expectations while some of the fast growers may not. We can look for possible exceptions in the height-change and quality-change patterns of our 18-inch red oak.

### Height Change

No luck here. Comparing trees that do not change in height with those that do, we see little difference in value increment:

| *Height change (feet)* | *Trees (no.)* | *Initial value* | *Future value* | *Value change* | *Average value change* | *Rate of value increase (percent)* |
|---|---|---|---|---|---|---|
| 0 | 388 | $1,094.16 | $2,133.64 | $1,039.48 | $2.68 | 6.9 |
| 16 | 12 | 33.84 | 58.70 | 24.86 | 2.07 | 5.7 |

Quality and time play an important part. Upper-stem logs that are added by grade-2 trees are usually poor-quality logs. Their conversion costs often exceed their 4/4 lumber value. They take time to develop quality and become more valuable. So, as long as the owner is interested in value changes over only a 10-year period, he might well instruct his timber-markers to avoid concerning themselves with upper-stem development possibilities. There is not much chance of an 18-inch red oak adding another log, anyhow.

### Tree-Quality Changes

But, on the other hand, he should instruct his markers to always consider the possibility of quality changes. For, comparing quality measures, we see some marked and important differences:

| *Change in butt-log grade* | *Trees (no.)* | *Initial value* | *Future value* | *Value change* | *Average value change* | *Rate of value increase (percent)* |
|---|---|---|---|---|---|---|
| From 2 to 3 | 89 | $250.98 | $–152.18 | $–403.16 | $–4.53 | (*) |
| No change | 268 | 755.76 | 1,738.59 | 982.83 | 3.67 | 8.7 |
| From 2 to 1 | 43 | 121.26 | 605.93 | 484.67 | 11.27 | 17.4 |

*Negative value.

Note the trees that improve in grade. They add, on the average, more than three times the value that unchanging trees add. Their rate of value increase is twice that of trees that do not improve in grade. These are the trees that are most likely to meet or exceed the owner's financial objectives. They include trees that might grow in diameter as little as 1 inch in 10 years. And the forest owner can anticipate 1 out of 11 18-inch, grade-2 red oaks to improve to grade 1 in 10 years.

The question is, which one? Though there is no sure answer, a woods-wise forester can often make a confident estimate based on an individual tree's unique external appearance. The difference in value increment may well be worth the cost involved with making the estimate.

Even the trees that remain grade 2 can be expected to increase in value at a respectable rate—8.7 percent on the average. The forest owner might happily note that he can expect two-thirds of his 18-inch grade-2 trees to do just that.

As for the trees that drop in grade: such changes can rarely be foreseen. But care can be taken in timber-marking to avoid setting up conditions that might prompt such changes: opening up a stand too much, allowing improper spacing, or leaving a quality tree in a large opening. Feathering—epicormic budding or branching—which often occurs under such conditions, can cause degrade. Being aware of the drastic losses in value that accompany degrade, the forest owner is apt to insist on a policy of proper density and spacing for a given site.

The following statements summarize our analysis of the development patterns in the 18-inch grade-2 red oaks in our forest.

1. Those trees with the potential of improving to grade 1 are potentially big earners.

2. Those that we expect to remain grade 2 are likely to increase in value at a rate that the forest owner deems adequate. Such trees make up the bulk of his 18-inch grade-2 red oaks. The faster these grow, the larger their value increment will be.

3. Those trees that drop in grade will become negative in value. That is, it would cost more to convert them into 4/4 lumber than the lumber would be worth.

4. Not many trees of this size should be expected to increase in merchantable height. Those that do usually have smaller value changes than trees whose sawlog height stays the same.

## CONCLUSIONS

Using tree-development probabilities to project sawtimber tree values has certain advantages. It allows us to:

- Project tree quality, which is often expressed in terms of discrete qualitative variables such as butt-log grade.
- Estimate the likelihood with which we can expect a tree to change in any one or any combination of ways.
- Make projections for a full range of tree-development possibilities, which does not limit us to average conditions.
- Use the resulting tree values and their probabilities to develop management-planning information pertinent to the timber owner's economic objectives.

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# The Commercial CAMPGROUND INDUSTRY in New Hampshire

## A Report on a 1971 Campground Census

by Wilbur F. LaPage
Paula L. Cormier
Steven C. Maurice

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WARREN T. DOOLITTLE, DIRECTOR

# The Commercial CAMPGROUND INDUSTRY in New Hampshire


## Abstract

The findings of a 1971 census of commercial camping enterprises in New Hampshire, including the growth of commercial camping enterprises during the period 1960-71, the average per-site costs and returns for operating a campground in 1970, and the characteristics of 78 successful and 89 unsuccessful camping enterprises.


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## THE AUTHORS

WILBUR F. LaPAGE is the leader of an outdoor recreation marketing research project of the USDA Forest Service, located at the Northeastern Forest Experiment Station's Forestry Sciences Laboratory in Durham, New Hampshire. He has been conducting research on the camping market and its investment opportunities since 1964.

PAULA L. CORMIER is a computer technician in the recreation research project at the Forestry Sciences Laboratory, Durham, New Hampshire. Ms. Cormier has a master's degree in mathematics from the University of New Hampshire.

STEVEN D. MAURICE is a resource planner with the U.S. Soil Conservation Service. At the time of this study, he was a research forester at the Forestry Sciences Laboratory, Durham, New Hampshire. Mr. Maurice has a master's degree in forest recreation management from Yale University.


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# THE GROWTH
# OF COMMERCIAL CAMPGROUNDS

DURING THE summers of 1964 and 1971, attempts were made to conduct complete censuses of commercial campgrounds in New Hampshire. In 1964, 108 campgrounds were located, and their owners were interviewed. In the 1971 census we found 189 camping enterprises in business and 24 under construction--an annual increase of 8.3 percent over the 7-year period.

Between these two censuses, 44 campgrounds were found to have gone out of business. An additional 13 campgrounds, known to exist before the 1964 census, were never located, which suggested that at least this many went out of business before 1964.

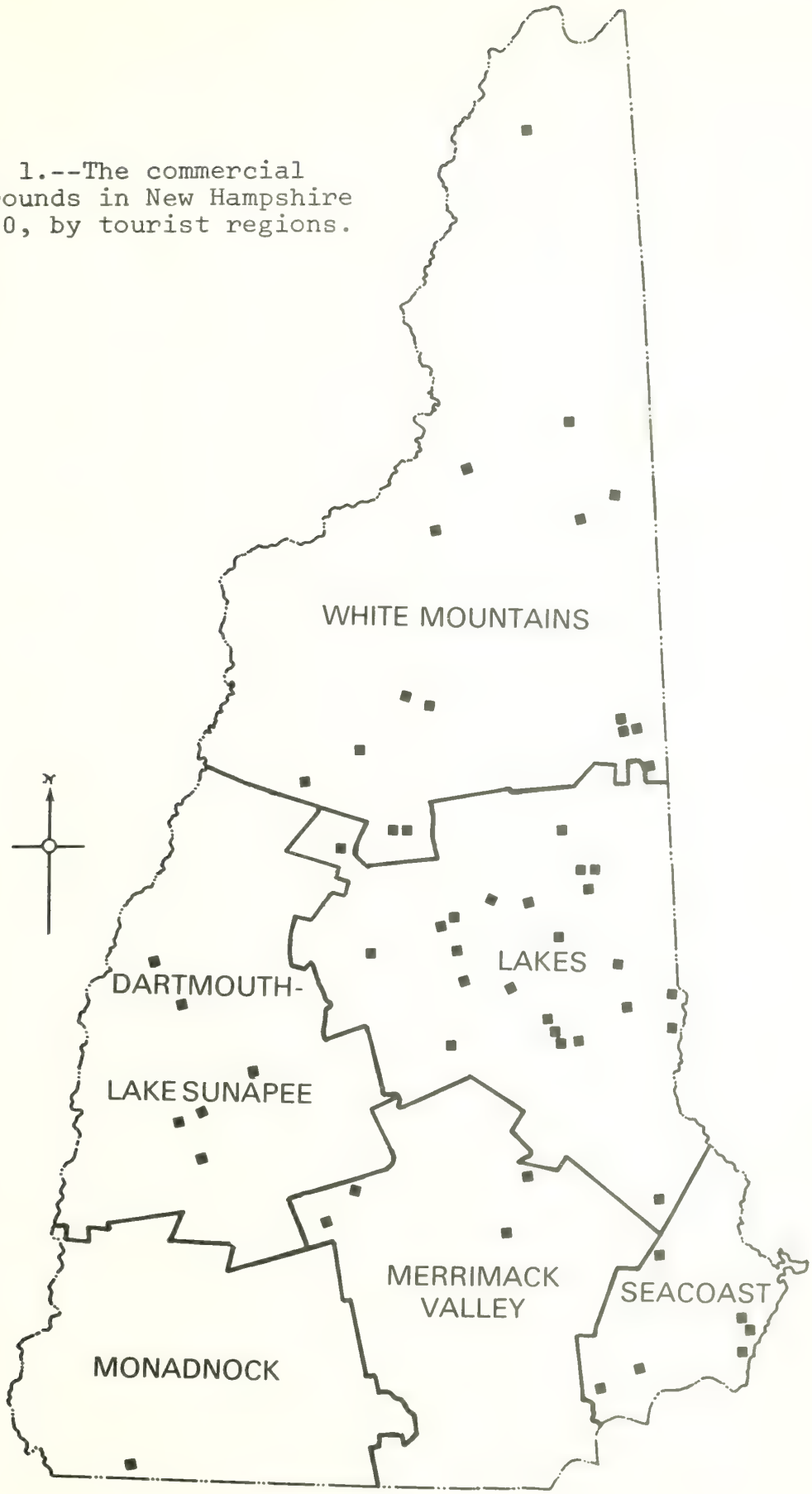
The regional distribution of commercial campground development activity revealed heavy concentration of new enterprises in the Lakes Region and White Mountain Region (table 1). The failure rate tends to be higher in these regions too. The average annual failure rate for campgrounds in New Hampshire's three northern tourist regions (Lakes, White Mountains, and Dartmouth-Lake Sunapee) for 1960-70 was 2.6 percent; while that for the three southern regions (Monadnock, Merrimack Valley, and Seacoast) was 1.0 percent (fig. 1).

Table 1.--Changes in New Hampshire camping enterprises, 1960-71, by county and region

| County or region | In business 1960 | Changes 1960-64 | | Changes 1965-70 | | New construction 1970-71 | Total new enterprises[1/] |
|---|---|---|---|---|---|---|---|
| | | Began | Failed | Began | Failed | | |
| County: | | | | | | | |
| Belknap | 10 | 5 | 1 | 12 | 3 | 2 | 29 |
| Carroll | 15 | 10 | 3 | 27 | 7 | 2 | 54 |
| Cheshire | 1 | 5 | 0 | 12 | 2 | 2 | 20 |
| Coos | 6 | 8 | 2 | 14 | 9 | 5 | 33 |
| Grafton | 9 | 12 | 2 | 16 | 14 | 7 | 44 |
| Hillsboro | 0 | 3 | 1 | 8 | 0 | 1 | 12 |
| Merrimack | 5 | 10 | 2 | 5 | 5 | 4 | 24 |
| Rockingham | 5 | 2 | 2 | 22 | 1 | 2 | 31 |
| Strafford | 2 | 6 | 0 | 6 | 1 | 0 | 14 |
| Sullivan | 4 | 3 | 0 | 3 | 2 | 0 | 10 |
| Total | 57 | 64 | 13 | 125 | 44 | 25 | 271 |
| Region: | | | | | | | |
| White Mountains | 15 | 26 | 6 | 24 | 20 | 10 | 75 |
| Dartmouth-Lake Sunapee | 7 | 10 | 1 | 9 | 8 | 0 | 26 |
| Lakes | 23 | 16 | 2 | 41 | 12 | 6 | 86 |
| Monadnock | 1 | 6 | 0 | 15 | 2 | 3 | 25 |
| Merrimack | 4 | 4 | 3 | 18 | 1 | 5 | 31 |
| Seacoast | 7 | 2 | 1 | 18 | 1 | 1 | 28 |
| Total | 57 | 64 | 13 | 125 | 44 | 25 | 271 |

[1/] Total of campgrounds in 1960 plus all new ones since 1960. The sum of new campgrounds and failures through 1970 is 189 campgrounds that were in business for the 1970 camping season. This report is based on 182 of those enterprises.

Figure 1.--The commercial campgrounds in New Hampshire in 1960, by tourist regions.



## SOME ECONOMICS OF CAMPGROUND OWNERSHIP

In addition to identifying market entries into and exits from the campground business, the 1971 census included data on the costs and returns of commercial campground operation from 182 enterprises that had been in business for at least 1 year. (Comparable information from a sample of campgrounds was collected simultaneously in 11 other Northeastern states as part of Regional Research Project NEM-42. When all these data have been analyzed, we should be able to compare campground costs and returns in New Hampshire with those in other Northeastern states.)

A few campground operators did not have, or were reluctant to divulge, figures on their costs and returns. Usable 1970 income data were provided by 129 out of 182 operators; and partial information on costs was provided for 144 campgrounds. Consequently, our cost-and-return data cannot be considered representative of the New Hampshire campground industry or any of its regional or investment-size groupings; they simply provide an interesting insight into those enterprises with available data.

ble 2.--Average gross income per campground site in 1970, and estimated total income for small, medium, and large campgrounds in New Hampshire, 1970[1/]

| Item | Fewer than 50 sites | 50-99 sites | 100 or more |
|---|---|---|---|
| mber of enterprises | 96 | 51 | 35 |
| an size, number of sites | 27 | 67 | 147 |
| mber of campgrounds providing income data | 68 | 38 | 23 |
| an income per site | $89.71 | $112.00 | $152.10 |
| nual income for an average enterprise | $2,422.00 | $7,504.00 | $22,359.00 |
| tal income of N. H. campgrounds (est.) | $232,512.00 | $382,704.00 | $782,565.00 |

[1/] Site rental income only. More than 88 percent of all campgrounds dicated that site rentals provided 90 to 100 percent of their total come in 1970.

Table 3.--Average annual expenditures of campgrounds for operating costs

| Item | Campgrounds reporting | Average cost per site | Estimated cost for average campground (62 sites) |
|---|---|---|---|
| | No. | Dollars | Dollars |
| Paid labor | 59 | 21.00 | 1,302.00 |
| Utilities | 121 | 10.55 | 654.10 |
| Vehicles | 105 | 9.40 | 582.80 |
| Taxes | 117 | 14.30 | 886.60 |
| Interest | 61 | 19.13 | 1,186.06 |
| Insurance | 126 | 5.27 | 326.74 |
| Maintenance | 117 | 14.70 | 911.40 |
| Advertising | 144 | 5.45 | 337.90 |
| Dues | 68 | 1.75 | 108.50 |
| Office supplies | 111 | 1.38 | 85.56 |
| Depreciation | 64 | 29.10 | 1,680.20 |
| Firewood | 42 | 2.67 | 165.54 |
| All costs | -- | 132.70 | 8,227.40 |

The size structure of the industry revealed a strong imbalance in favor of smaller and less economic units (table 2). Most of New Hampshire's campgrounds are small. Those having fewer than 50 tent or trailer units constitute 53 percent of the total and reported an average gross 1970 income from site rentals of less than $2,500. Another 28 percent of New Hampshire's campgrounds had between 50 and 99 campsites--averaging 67 units--and reported an average 1970 gross income of less than $7,500.

Campgrounds having more than 99 sites included 19 percent of the total, averaging 147 sites, and had an average gross income of nearly $22,500 from campsite rentals in 1970.

A complete accounting of the costs of operating a campground was provided by relatively few owners. However, enough data were collected on major cost items to produce a partial picture of net revenues from site rentals (table 3).

Of 23 small campgrounds (fewer than 50 sites) that provided complete records, 10 reported losses ranging from $24 to $147 per site. The mean net income for the group responding was $4.60 per site or $124.20 for an average small campground of 27 sites.

Of 10 medium-size campgrounds reporting costs and income, 3 had per-site losses of $83 to $90. And the average net income for the 10 campgrounds was $15.80 per site or $1,058.60 for an average medium-size campground of 67 sites.

Three of the 13 largest campgrounds (more than 99 sites) reported losses ranging from $14 to $88 per site. The average net income for these 13 campgrounds was $47.90 per site or $7,041.30 for an average large campground of 147 sites.

An overall average of $9.50 net per site from store sales and other sources of campground income could be added to the above figures. However, not all campgrounds have these additional incomes; and for those that do, these figures tend to exaggerate the relationships between campground size and net income. For example, only 29 percent of the small campgrounds had sources of campground income other than site rentals. At medium-size campgrounds and large campgrounds those having store income were 49 and 54 percent respectively.

The average operating expenses (table 3) provided a way of estimating the operating costs for any size of campground by multiplying item costs by number of sites in the campground. Item costs and total estimated costs were calculated for an average campground (in 1970) of 62 sites. For purposes of comparison, the average gross income per site for a campground of this size was approximately $112.

A simple comparison of costs and returns revealed that the average campground will not break even unless: (1) the owner can avoid paying for labor and ignore depreciation, which is probably what a great many campground owners have done in order to stay in business; or (2) the campsite rental income can be supplemented by additional revenues that will net at least 19¢ for every $1 of campsite rentals.

The relationship between large campgrounds and more income per site may be in part a function of the regional distribution of campgrounds. Campgrounds of more than 50 sites were in the minority in every region except the Seacoast (table 4).

Table 4.--Regional size distribution of campgrounds and mean gross site-rental incomes of responding campgrounds[1/]

| Region | Small campgrounds[2/] | | | Medium and large campgrounds | | |
|---|---|---|---|---|---|---|
| | Proportion of regional total | Mean size (sites) | Mean gross income | Proportion of regional total | Mean size (sites) | Mean gross income |
| | Percent | No. | Dollars | Percent | No. | Dollars |
| 1. White Mountains | 62 | 24 | 2,184 | 38 | 103 | 17,716 |
| 2. Dartmouth-Lake Sunapee | 71 | 22 | 1,430 | 29 | 61 | 6,710 |
| 3. Lakes | 51 | 28 | 2,418 | 49 | 115 | 14,950 |
| 4. Monadnock | 55 | 32 | 2,240 | 45 | 74 | 8,436 |
| 5. Merrimack | 59 | 28 | 2,464 | 41 | 90 | 9,270 |
| 6. Seacoast | 22 | 29 | 2,668 | 78 | 97 | 10,864 |
| All regions | 53 | 27 | 2,430 | 47 | 99 | 12,573 |

[1/] Average incomes are based on 19 of 24 small and 10 of 15 large campgrounds in region 1. The corresponding ratios for the other regions are: region 2, 9/12 and 4/5; region 3, 19/31 and 21/30; region 4, 10/11 and 6/9; region 5, 9/13 and 8/9; region 6, 2/5 and 12/18.

[2/] Fewer than 50 sites.

## MANAGEMENT PRACTICES

A major objective of the 1971 census was to identify and evaluate the marketing and pricing practices of commercial campgrounds. This part of the study included three broad classes of management activity: pricing, promotion, and facilities and services offered to the camping public.

### Pricing and Charging Practices

The most common daily rates charged at New Hampshire campgrounds in 1970 were:

| | |
|---|---|
| Tent sites; no utility hookups | $3.00 |
| Campsite with electricity or water connections | $3.50 |
| Campsite with electricity, water, and sewage connections | $4.00 |

Approximately one-third of all managers raised their rates by 50¢ for the 1971 season. Twenty-one percent planned to raise their rates in 1972 and another 28 percent were considering an increase for the 1972 season.

The comparison of average per-site fees did not imply that most campgrounds charged on a per-site basis. In fact, most had a per-family charge, although there was no uniform definition of a family, and a few charged on a per-person basis. In 1970 the basic units for charging at 182 commercial campgrounds in New Hampshire were:

| Basis | Campgrounds |
|---|---|
| Per site | 30 |
| Per family-- | |
| of 2 | 7 |
| of 3 | 1 |
| of 4 | 35 |
| of 5 | 38 |
| of unlimited size | 60 |
| Per person-- | |
| over 12 years old | 10 |
| over 18 years old | 1 |

The 1964 census did not include comparable data on methods of charging. However, most managers indicated that the trend has been away from per-site fees and toward more complex fee systems. For example, a campground may have fee zones and charge higher rates for sites near the waterfront. Size of family, type of utility connections, and length of visit can all influence the fee. And a few campgrounds have off-season rates. Most campgrounds also charge $1 to $2 for visitors to the campsite.

Seasonal camping rates ranged from $80 to $330. Of the 126 campgrounds that had seasonal rates, one-half were in the $150 to $200 range. About 40 percent of the campgrounds allowed campers to store their equipment on sites during the off-season. Most of these had no extra charge for this service, and did it as a courtesy for their seasonal campers.

A minority of campgrounds (42 percent) allowed large groups to camp in their areas and about two-thirds of these offered special group rates. These rates were usually negotiated individually, depending on the size of the group and the time of year.

A majority of campgrounds (75 percent) did not allow picnicking or other forms of day use in the campground. Relatively few had separate picnic and day-use areas.

Only 13 campgrounds were found to accept credit-card payments for campsite rentals.

## Promotional Practices

The average per-site expenditure for advertising varied with the campgrounds' size and location (table 5). The average in the three northern regions was more than twice that of the three southern regions. Variations by size within region were substantial but followed no consistent pattern from one region to another. The differences in mean advertising expense also had no consistent relationship with age or size of camping enterprise (table 6).

Table 5.--Average per-site expenditures for advertising, by region and size of campground

[Ratio of responding campgrounds is shown in parentheses]

| Region | Small campgrounds[1/] | Large campgrounds | All campgrounds |
|---|---|---|---|
| White Mountain | $9.00 (23/24) | $5.90 (10/15) | $8.06 |
| Dartmouth-Lake Sunapee | 5.50 (10/12) | 4.30 (3/5) | 5.22 |
| Lakes | 3.70 (21/31) | 8.30 (24/30) | 6.15 |
| Monadnock | 3.80 (8/11) | 3.30 (7/9) | 3.57 |
| Merrimack Valley | 3.60 (10/13) | 2.20 (9/9) | 2.94 |
| Seacoast | 2.80 (4/5) | 3.50 (15/18) | 3.35 |
| All regions | $5.49 | $5.39 | $5.45 |

[1/] Small campgrounds have fewer than 50 campsites, large campgrounds have 50 or more.

Table 6.--Average per-site expenditures for advertising in 1970, by campground age and size

| Years in business | Small campgrounds | Large campgrounds |
|---|---|---|
| At least 6 | $4.60 | $6.10 |
| 5 or less | 6.10 | 4.70 |

Most of the reported expenditure went for two types of advertising: (1) printing and distribution of brochures; and (2) advertisements in camping magazines and directories. Eighteen campgrounds bought advertising space in newspapers. Five campgrounds advertised on local radio and television stations. Fifty-five campground owners had evaluated the effectiveness of specific advertising outlets in the past, and 42 of these felt that ads in directories and camping magazines were their best buy.

The number and variety of promotional activities seemed to be severely limited. Two campgrounds provided a day's free camping--at the beginning of the season; and 28 campgrounds featured a campground supper at some time during the season. Thirty-eight campgrounds had no printed brochures; and only 14 campgrounds distributed their brochures through four or more outlets, such as camping shows, equipment dealers, tourist booths, and direct mail.

## Facilities and Services Provided

Several of the services and some of the facilities provided by campgrounds had distinct promotional value. For example, 124 campgrounds had an informal referral arrangement with neighboring campgrounds on peak-use days.

Nine of ten campgrounds accepted reservations, and 90 percent of these would reserve a specific numbered campsite on request. Campsites reserved in advance accounted for more than one-half of the business at one of every two campgrounds. Relatively few (11) campgrounds had policies of not accepting reservations on holiday weekends. And a minimum length of visit--usually 1 week--was required by only two campgrounds. The off-season storage of recreational vehicles, discount rates for groups, and restrictions on pets were other examples of services with promotional value.

An abundance of available campsites is both a service and a facility for camping tourists. The 182 campgrounds in operation in 1970 had a developed capacity of 11,123 campsites, not including overflow capacity and undeveloped campsites. This was an increase of 171 percent over the estimated 4,100 developed sites reported in the 1964 census.

All but 11 of the 182 campgrounds had some campsites with utility connections for electricity or water and sewage. Seventy percent of the 11,123 campsites had at least an electrical connection. The average campground of 62 sites had 19 tent sites (no hookups) and 43 sites with some combination of utility connections. In 1964, the average commercial campground in New Hampshire had about 40 campsites evenly split for tents and trailers. The majority of commercial campgrounds in 1970 offered hot showers (76 percent); flush toilets (89 percent); dumping stations for trailer holding tanks (57 percent); firewood, but generally not free (75 percent); fishing (78 percent); and swimming beaches (61 percent).

A minority offered organized activities and rentals of recreational equipment. Other facilities and services offered included:

| | (Percent) |
|---|---|
| Playground | 73 |
| Camp store | 42 |
| Boat-launching area | 28 |
| Recreation hall | 26 |
| Rental boats | 26 |
| Gas or propane service | 20 |
| Washers, dryers | 19 |
| Dock space | 18 |
| Juke box or record player | 16 |
| Marked nature trails | 13 |
| Snack bar or restaurant | 9 |
| Swimming pool | 5 |
| Baby-sitting | 5 |
| Rental tents | 5 |
| Rental trailers | 3 |
| Riding horses | 2 |

## VOLUME OF BUSINESS

The average attendance at commercial campgrounds in New Hampshire doubled between 1963 and 1970. The number of camping parties (families) averaged 800 per campground in 1970. However, one-half of the campgrounds had fewer than 375 parties. By comparison, 34 of 71 campgrounds in 1963 had fewer than 100 camping parties. The average occupancy rates were significantly higher at large campgrounds and at campgrounds in the Lakes Region (table 7).

The average occupancy (June, July, and August) for all campgrounds was about 50 percent. Weekdays averaged about 40 percent and weekends about 65 percent. On holiday weekends in 1970, the average occupancy level was 80 percent. The most common visit to New Hampshire campgrounds was for a weekend:

| Length of visit | Campgrounds (No.) |
|---|---|
| 1 day | 27 |
| Weekend | 77 |
| 4 to 7 days | 24 |
| Over 1 week | 22 |
| Seasonal | 12 |

Table 7.--Average 1970 summer occupancy of New Hampshire campgrounds, by regions and size of campground

[In percent of occupancy]

| Region | Small campgrounds | Large campgrounds |
|---|---|---|
| White Mountain | 47 | 72 |
| Dartmouth-Lake Sunapee | 35 | 55 |
| Lakes | 61 | 70 |
| Monadnock | 38 | 55 |
| Merrimack Valley | 45 | 70 |
| Seacoast | 25 | 80 |

This distribution tends to de-emphasize the importance of long visits. Almost all campgrounds rented some sites to season-long campers and 16 percent rented at least one-half of their campsites to campers who stayed for the full season. Full-season rentals are most common in the Lakes Region and Seacoast Region, accounting for more than 1/8 of the business in these regions. In 1970, managers reported that, on the average, about 60 percent of their visitors were repeat customers. Most managers reported that this percentage of repeat business has remained fairly constant since 1968.

Throughout the State, commercial campgrounds were located, on the average, only about 14 miles from a federal, state, or county-operated campground. Most campground owners (60 percent) felt that the public campgrounds had no effect on their business. Smaller campgrounds and those situated in regions having large public campground developments were more likely to report that public developments hurt their business (table 8).

Table 8.--Percent of commercial campgrounds reporting a business reduction due to their location near public campgrounds, by size of enterprise and region

| Region | Small campgrounds | Large campgrounds |
|---|---|---|
| White Mountains | 54 | 15 |
| Dartmouth-Lake Sunapee | 20 | 10 |
| Lakes | 11 | 21 |
| Monadnock | 18 | 0 |
| Merrimack Valley | 17 | 25 |
| Seacoast | 0 | 12 |

## CHARACTERISTICS OF SUCCESSFUL CAMPGROUNDS

Success in any business is equated with profitability. Profitability in the campground business is difficult to determine for a variety of reasons--most commonly, inadequate cost records. Many campground owners have other sources of income and apparently feel that they can afford to put more money into the campground than they can get out of it in the short run. Of the 182 campgrounds surveyed, only 46 could supply complete records on both costs and returns; and 16 of these showed a net loss in 1970. Consequently, an examination of enterprise success must be based on some arbitrary definition of the term.

An alternative criterion of success is whether or not the campground has the volume of business it needs to succeed. The average (median) daily summer occupancy in 1970 for New Hampshire campgrounds was 60 percent. The average (mean) gross income per site was $107 (excluding store sales).

Campgrounds that exceeded the average in either or both of these measures could logically be considered to have the potential for success. And campgrounds with below-average attendance but higher-than-average gross income per site should also be considered successful because their pricing practices may be more realistic than the average. The distribution of 182 campgrounds in 1970 according to these two criteria was:

| | No. |
|---|---|
| Successful: | |
| 1. Above-average occupancy, over $107/site: | 48 |
| 2. Above-average occupancy, income unknown: | 21 |
| 3. Below-average occupancy, over $107/site: | 8 |
| 4. Occupancy unknown, over $107/site: | 1 |
| Total | 78 |
| Unsuccessful: | |
| 1. Below-average occupancy and income: | 46 |
| 2. Below-average occupancy, income unknown: | 17 |
| 3. Above-average occupancy, under $107/site: | 19 |
| 4. Occupancy unknown, under $107/site: | 7 |
| Total | 89 |
| Unknown: | |
| 1. Occupancy unknown, income unknown: | 15 |

A comparison of the 78 successful and 89 unsuccessful campgrounds revealed a number of significant differences in their operations (table 9). The successful enterprises were larger, and more than two-thirds of their sites had complete or partial utility connections for travel trailers. The market value of the successful enterprises and the average cost per site of operating them were about twice that of unsuccessful campgrounds. And the average number of camping parties served was almost four times greater at successful campgrounds.

Years of operation seems to be associated with success. Eighty-one percent of the successful enterprises and 59 percent of the unsuccessful enterprises had been in business for at least 5 years. Years of operation is probably also related to the number of repeat visitors and the average length of a camping visit. The modal length of visit at 83 percent of the unsuccessful campgrounds was only 1 to 2 nights. Such short visits were the rule at only 44 percent of the successful enterprises.

Table 9.--A comparison of 78 successful and 89 unsuccessful commercial campground operations in New Hampshire in 1970

| Factor | Successful | Unsuccessful |
|---|---|---|
| Size: | | |
| Tent sites in 1964[1/].....number.... | 20 | 15 |
| Trailer sites in 1964[1/]...number.... | 20 | 15 |
| Tent sites in 1970.....number.... | 21 | 17 |
| Trailer sites in 1970.....number.... | 50 | 32 |
| Volume of business: | | |
| Mean number of parties....number.... | 1,361 | 362 |
| Seasonal visitors[2/].....percent.... | 31 | 10 |
| Repeat business increasing..percent. | 40 | 26 |
| Costs per developed campsite: | | |
| Total.....dollars.... | 144.30 | 67.50 |
| Taxes .....dollars.... | 17.60 | 10.80 |
| Interest on loans.....dollars.... | 12.30 | 7.30 |
| Maintenance.....dollars.... | 20.90 | 9.20 |
| Advertising.....dollars.... | 6.30 | 4.70 |
| Depreciation.....dollars.... | 36.70 | 18.70 |
| Paid labor.....dollars.... | 23.00 | 10.90 |
| Average fair market value (1970) (estimated).....dollars..... | 145,000.00 | 86,000.00 |

[1/] Average for those campgrounds in business in 1964.

[2/] At least 10 percent of sites were rented at seasonal rate.

A number of other differences suggested that the successful enterprises have a more businesslike management. For example, 66 percent of the successful operators had a charge for campers' visitors, averaging $1.75 per car. At unsuccessful operations, the figures were 49 percent and $1.25. The proportion of campgrounds that had store sales to supplement their campsite rental income was 1 out of 5 for both categories of campgrounds. However, the successful ones averaged $11.40 (net) per site versus $7.80 for the unsuccessful ones. Membership in campground owner associations was more common (60 percent versus 38 percent) among the successful campgrounds.

The range in net incomes (per site, excluding store sales) among successful campgrounds was far greater than it was for the unsuccessful ones. The latter ranged from -$88 per site to +$57 per site. Successful enterprises ranged from -$147 to +$251 per site, a mean of $36 net income per site.

Unsuccessful operators were more likely to have developed land that had been in their family rather than to have selected the land because it seemed to have campground potential (40 percent versus 6 percent "in the family" among successful operators). The importance of carefully selecting the location for a camping enterprise is most apparent when comparing success ratios by county (fig. 2):

| County | 1970 campgrounds (No.) | Successful (percent) |
|---|---|---|
| Belknap | 22 | 36 |
| Carroll | 37 | 57 |
| Cheshire | 16 | 56 |
| Coos | 16 | 44 |
| Grafton | 22 | 9 |
| Hillsboro | 9 | 22 |
| Merrimack | 14 | 43 |
| Rockingham | 25 | 60 |
| Strafford | 12 | 31 |
| Sullivan | 9 | 44 |

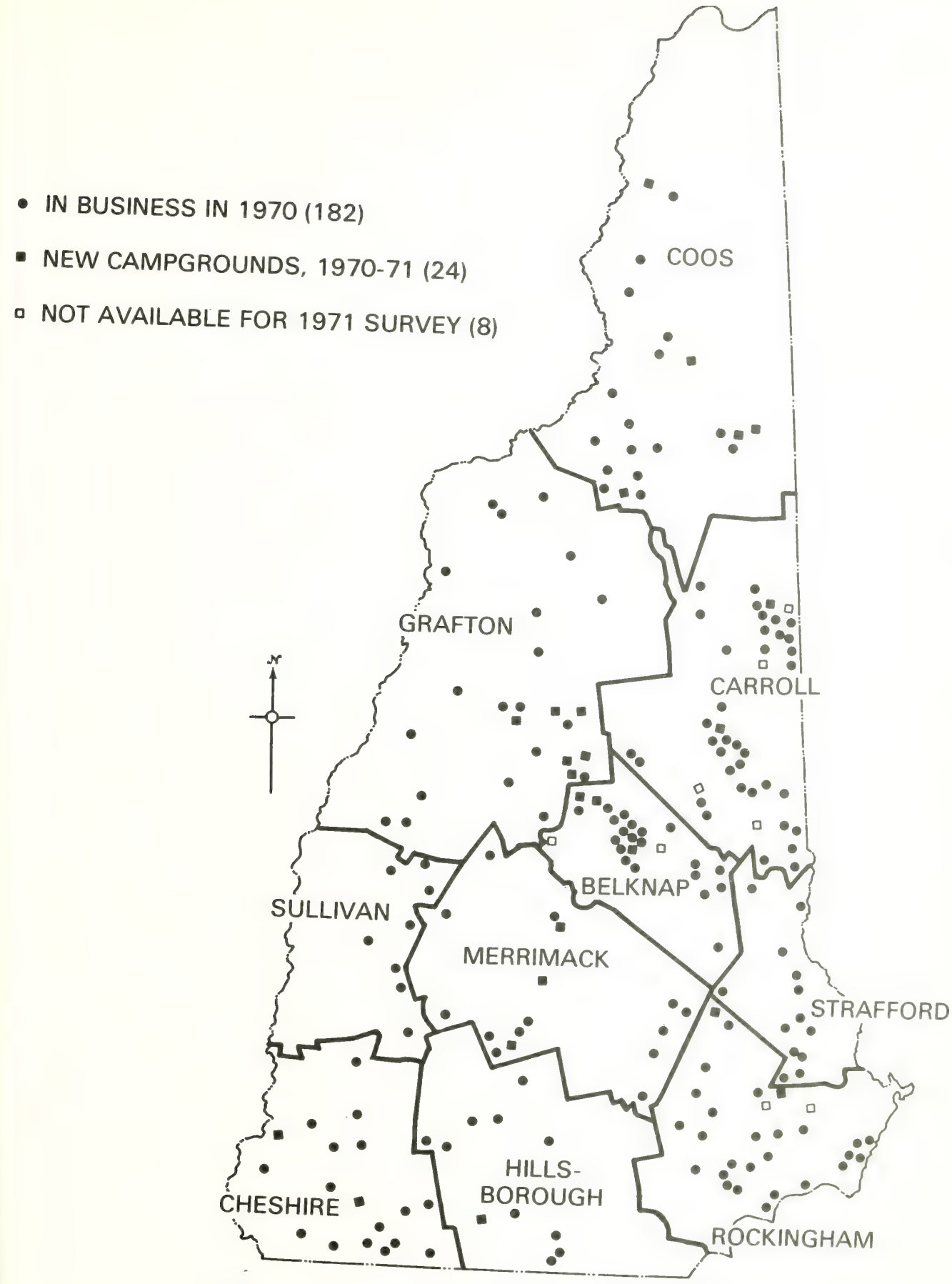



Figure 2.--The commercial campgrounds in New Hampshire in 1971, by counties.

## SUMMARY AND CONCLUSIONS

The size, growth, and geographic distribution (figs. 1 and 2) of the campground industry in New Hampshire is impressive. Through private investment, the state has acquired a major developed resource that provides outdoor recreation and helps to generate tourist expenditures. It is a resource that emphatically contributes answers to the 1962 Outdoor Recreation Resources Review Commission's recommendations of providing, through private investment, outdoor recreation opportunities nearer to our major centers of population. And it is a resource that could never have been duplicated through public acquisition and agency growth. Yet it is an industry in trouble. Its growth, in terms of enterprises and capacity to serve the camping public, has been good. But its growth in terms of earnings has been a disappointment to many investors. Despite an incomplete and not totally representative census in 1971, it is clear that returns and costs are out of balance--particularly among small enterprises of fewer than 100 tent and trailer sites.

The strong relationship between campground size and net return is alarming on two counts: (1) most (8 out of 10) of New Hampshire's commercial campgrounds have fewer than 100 developed sites; and (2) the trend toward larger campground developments seems to be at odds with the needs for variety, personal service, and well-distributed camping opportunities for a vigorous tourist economy.

As a further result of poor earnings, campground owners are sometimes forced to develop supplemental campground income through the sale of souvenirs, firewood, and ice, and through other activities that may, in the long run, detract from the business of providing enjoyable experiences that will draw campers back to New Hampshire for future visits.

The finding that a relatively large number of campground enterprises were developed as a means of earning income from land already owned, and that very few such enterprises were successful, is an important one. Lacking a careful site selection, many of these enterprises have little potential for success. Consequently, their earnings and volume-of-business statistics tend to dampen the outlook for the industry as a whole.

In part, the poor earning record of commercial campgrounds must be due to the owners' reluctance to raise their rates. The more impressive earnings of large campgrounds are not entirely due to their size. Larger campgrounds are more likely to have income sources other than site rentals, and their site rentals tend to be higher as well. Because of the density of commercial campgrounds in parts of the State, there may be a feeling that rates must be raised collectively or not at all. And in some tourist regions, particularly the White Mountains, there is probably a feeling that it is necessary to set rates that will be comparable with those at the State Parks and National Forest campgrounds.

The assumptions that rates should be raised collectively, and that they should be comparable with those at public parks, reflect a poor understanding of the camping product. An independent increase of 50¢ or even $1 per night will probably not send campers flocking to the cheapest competition--particularly if the fees reflect quality development and service. Those campgrounds that have raised their rates in the past have apparently not lost any appreciable number of campers. And there seems to be some evidence to support the idea that public and private campgrounds are increasingly less competitive. Relatively few campgrounds developed at public expense are designed and managed at the level required by today's sophisticated recreational vehicles.

Raising camping fees to a level that more accurately reflects costs seem to be the top-priority order of business for the industry as a whole. Many New Hampshire campgrounds have apparently been losing money for years; and unless this trend is reversed, we may shortly be faced with a period of many campground failures at a time when the number of campers in the market continues to increase.

More realistic camping-fee levels must be accompanied by a stronger emphasis on quality and public recognition of the camping enterprise as an economic resource. Relatively modest property-tax relief, which communities commonly have used to attract industries--and less clean industries than camping--could easily be justified on a local and broader basis. Locally, the campground generates jobs and income. But on a broader scale, if camping enterprises do not meet the demands of the camping public, then resource agencies will be forced to fill the gap at a considerable taxpayer expense.

Along with a failure to establish cost-based fees, campground owners in general seem to be guilty of unimaginative marketing and poor product identification. The product being offered to the camping public, at destination campgrounds at least, is daytime recreation. But the fee is always based on night-time accommodation. A $3.50 average for a day's recreation for a family is an outstanding bargain! In fact it is such a good bargain that it is equivalent to an industry-wide loss-leader that encourages sales of expensive camping equipment and vehicles.

When the campground industry begins to market and sell outdoor fun--rather than tent and trailer spaces--it will probably become a significant contributor to the State's economy. It is already a significant part of New Hampshire's total recreation resource.

## APPENDIX

Table 10.--A comparison of campground volume of business statistics according to enterprise size and regional location

| Region and size of campground | Campgrounds | 100-day season or shorter | Reservations are 1/2 or more of business | Gross income per site (less store sales) | |
|---|---|---|---|---|---|
| | | | | Range | Mean |
| | No. | Percent | Percent | Dollars | Dollars |
| White Mountains: | | | | | |
| Small[1/] | 24 | 78 | 26 | 6-250 | 91 |
| Large | 15 | 60 | 50 | 6-333 | 172 |
| Dartmouth-Lake Sunapee: | | | | | |
| Small | 12 | 83 | 40 | 16-146 | 65 |
| Large | 5 | 60 | 80 | 77-177 | 110 |
| Lakes: | | | | | |
| Small | 31 | 87 | 50 | 10-293 | 111 |
| Large | 30 | 73 | 50 | 13-425 | 130 |
| Monadnock: | | | | | |
| Small | 11 | 55 | 38 | 4-170 | 70 |
| Large | 9 | 33 | 68 | 20-324 | 114 |
| Merrimack Valley: | | | | | |
| Small | 13 | 77 | 60 | 3-177 | 88 |
| Large | 9 | 78 | 25 | 40-171 | 103 |
| Seacoast: | | | | | |
| Small | 5 | 100 | 25 | 30-155 | 93 |
| Large | 18 | 61 | 59 | 8-265 | 112 |

[1/] Small campgrounds have fewer than 50 campsites.

Table 11.--A comparison of selected characteristics of camping enterprises in New Hampshire, based upon age and size of campground

| Characteristic | Old campgrounds[1] | | New campgrounds | |
|---|---|---|---|---|
| | Small[2] | Large | Small | Large |
| Enterprises ..... No. .. | 42 | 41 | 54 | 45 |
| Average size ..... No. sites .. | 29 | 100 | 26 | 99 |
| Sites per acre ..... No. .. | 4.9 | 6.1 | 4.7 | 5.5 |
| 1970 attendance ..... families .. | 428 | 1,108 | 362 | 1,422 |
| Average weekly rate ..... dollars .. | 18 | 21 | 19 | 21 |
| Average seasonal rate ... dollars .. | 150 | 170 | 180 | 200 |
| Over 1/2 full, 1970 ..... percent .. | 58 | 90 | 49 | 61 |
| Over 1/2 repeat visits .. percent .. | 81 | 90 | 53 | 79 |
| Over 1/2 reserved business ..... percent .. | 53 | 59 | 33 | 47 |
| Average market value .... dollars .. | 46,600 | 158,600 | 45,200 | 155,600 |
| Average income per site (excluding store sales).. dollars .. | 90.70 | 142.80 | 89.30 | 110.90 |
| Average net income per site from store sales ... dollars .. | 6.50 | 9.30 | 14.40 | 8.60 |
| Average costs per site (excluding store costs).. dollars .. | 90.80 | 106.00 | 118.20 | 114.30 |
| Average costs per site (without store): | | | | |
| Labor ..... dollars .. | 8.60 | 18.60 | 3.90 | 20.20 |
| Taxes ..... dollars .. | 19.80 | 10.00 | 17.00 | 12.50 |
| Interest ..... dollars .. | 5.90 | 6.20 | 9.60 | 15.80 |
| Advertising ..... dollars .. | 4.60 | 6.10 | 6.10 | 4.70 |
| Depreciation ..... dollars .. | 15.90 | 28.70 | 30.70 | 30.50 |
| Regional distribution: | | | | |
| White Mountains ..... percent .. | 28 | 15 | 34 | 23 |
| Dartmouth-Lake Sunapee. percent .. | 35 | 6 | 35 | 24 |
| Lakes ..... percent .. | 23 | 23 | 28 | 26 |
| Monadnock ..... percent .. | 20 | 20 | 35 | 25 |
| Merrimack Valley ..... percent .. | 27 | 23 | 32 | 18 |
| Seacoast ..... percent .. | 4 | 48 | 17 | 31 |

[1] Older campgrounds in business before 1966; new campgrounds since 1966.

[2] Smaller campgrounds have fewer than 50 sites.

LIBRARY CARD

LaPage, Wilbur F., Paula L. Cormier, and Steven C. Maurice. 1972. THE COMMERCIAL CAMPGROUND INDUSTRY IN NEW HAMPSHIRE. NE. Forest Exp. Sta., Upper Darby, Pa. 41 p., illus. (USDA Forest Serv. Res. Pap. NE-255)

The findings of a 1971 census of commercial camping enterprises in New Hampshire, including the growth of commercial camping enterprises during the period 1960-71, the average per-site costs and returns for operating a campground in 1970, and the characteristics of 78 successful and 89 unsuccessful camping enterprises.

627.3 : 907.2 : (742)

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by Leland F. Hanks

MAY 10

# Green Lumber Grade Yields for Subfactory Class Hardwood Logs

USDA FOREST SERVICE RESEARCH PAPER NE-256
1973

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

## The Author

LELAND F. HANKS received his B.S. degree in forest management and his M.S. degree in forest mensuration from Iowa State University. During the summer of 1961, he worked for the Forest Service in Washington, D. C., and accepted a position with the Central States Forest Experiment Station in 1962. He is now a research forest products technologist with the Northeastern Station's project on quality and grade of hardwood timber at Columbus, Ohio.

MANUSCRIPT RECEIVED FOR PUBLICATION 8 JUNE 1972

# Green Lumber Grade Yields for Subfactory Class Hardwood Logs


## ABSTRACT

Data on lumber grade yields for subfactory class logs are presented for ten species of hardwoods. Logs of this type are expected to assume greater importance in the market. The yields, when coupled with lumber prices, will be useful to sawmill operators for developing log prices in terms of standard factory lumber.


## Introduction

LUMBER GRADE yield tables for subfactory class red oak sawlogs were reported previously by Schroeder in 1968.[1] Since then, there have been requests for tables of subfactory class lumber yields of additional species. We have developed such tables for nine more hardwood species: beech, hickory, red maple, yellow-poplar, yellow and paper birch, and white, chestnut, and overcup oak. These are presented in this report together with yields for red oak, thus bringing all available subfactory class yields under one cover.

## Procedure

During the past 12 years, the Forest Service has collected lumber grade yield data from approximately 12,000 hardwood logs. Although most of these qualified as factory grade 3 or better, over 600 subfactory class logs were sawed. Subfactory logs include construction and local-use classes. Specifications for these classes appear in tables 1 and 2, respectively. All lumber was graded by a National Hardwood Lumber Association inspector at the time of sawing, and the necessary information was recorded so that the board grades and volumes for each log were known.

In preparation for this report, we tabulated actual green lumber grade yields by log diameter for each species. These yields formed the basis for the analysis. Several species were eliminated from the study at this stage because the sample size or range of diameters was too small to be useful in yield table development. Multiple regression equations were derived for each lumber grade within a species. The equations were of the form:

$$\% \text{ yield} = a + b\,(\text{scaling diameter}) + c\,(\text{scaling diameter})^2$$

## Results

Tables 3 through 12 show the green lumber grade yields for subfactory class logs. Most major hardwood species have been considered, with the notable exception of sugar maple. Of the 613 sugar maple logs available, only three were classed as subfactory. If a subfactory yield table for sugar maple is required, the table for red maple is suggested as a substitute.

[1]Schroeder, James G. 1968. LUMBER GRADE YIELDS FOR SUBFACTORY CLASS RED OAK LOGS. USDA Forest Serv. Res. Paper NE-114, 15 p., NE. Forest Exp. Sta., Upper Darby, Pa.

It should be noted that the yields in table 3 were developed from the same logs used for Schroeder's earlier publication. A comparison will show differences. An obvious reason is that yields presented here are green yields while the earlier report presented dry yields. Most mills that saw subfactory class logs are producing lumber for the pallet industry, and the biggest share of pallet lumber is traded green. A possible reason for the differences between our yields and Schroeder's is that we used regression analysis instead of a hand fitting procedure. As a check, we compared the dry yields reported in NE-114, which were developed using hand fitted curves, with dry yields computed from our equations and found close agreement. Only 6 of the 66 figures differed by more than one percent. This finding justifies use of the much faster equation solving method.

## Discussion

Requests for data on subfactory class lumber yields have come from several sources. These logs are being converted into lumber, so buyers and sellers need to know the log values in terms of lumber. By applying prices to the yields, these log values can be determined.

As we approach utilization of the whole tree, more low quality logs will be marketed. The most profitable use of these logs must be determined, and yield data for subfactory class logs will be useful.

Table 1.—*Forest Service standard specifications for hardwood construction logs.*[a]

| | | |
|---|---|---|
| Position in tree | | Butt & upper |
| Min. diameter, small end | | 8 inches + |
| Min. length, without trim | | 8 feet |
| Clear cuttings | | No requirements. |
| Sweep allowance, absolute | | ¼ diameter small end for each 8 feet of length. |
| Sound surface defects | Single knots | Any number, if no one knot has an average diameter above the callus in excess of ⅓ of log diameter at point of occurrence. |
| | Whorled knots | Any number if sum of knot diameters above the callus does not exceed ⅓ of log diameter at point of occurrence. |
| | Holes | Any number provided none has a diameter over ⅓ of log diameter at point of occurrence, and none extends over 3 inches into included timber.[b] |
| Unsound surface defects | | Same requirements as for sound defects if they extend into included timber.[b] No limit if they do not. |
| End defects | Sound | No requirements. |
| | Unsound | None allowed; log must be sound internally, but will admit 1 shake not to exceed ¼ the scaling diameter and a longitudinal split not extending over 5 inches into the contained timber. |

[a] These specifications are minimum for the class. If, from a group of logs, factory logs are selected first, thus leaving only non-factory logs from which to select construction logs, then the quality range of the construction logs so selected is limited, and the class may be considered a grade. If selection for construction logs is given first priority, then it may be necessary to subdivide the class into grades.

[b] Included timber is always square, and dimension is judged from small end.

*From:* Rast, Everette D., David L. Sonderman, and Glenn L. Gammon. 1973. A GUIDE TO HARDWOOD LOG GRADING (Revised). USDA Forest Serv. Gen. Tech. Rep. NE-1. 32 p., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Table 2.—*Suggested specifications for hardwood local-use logs.*

| | |
|---|---|
| Position in tree | Butt and upper |
| Min. diameter, small end | 8 inches + |
| Min. length, without trim | 8 feet + |
| Sweep allowance, absolute | ½ diameter of small end |
| Max. scale deduction allowed | ⅔ |
| Clear cuttings | No requirements |
| Sound or unsound surface defect limitations | Only requirement is that diameter of knots, holes, rot, etc. shall not exceed ½ diameter of log at point of occurrence. |
| Sound end defects | No requirements |

*From:* Rast, Everette D., David L. Sonderman, and Glenn L. Gammon. 1973. A GUIDE TO HARDWOOD LOG GRADING (Revised). USDA Forest Serv. Gen. Tech. Rep. NE-1. 32 p., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Table 3.—*Green lumber yields by grade for construction and local-use class red oak sawlogs*[a]

| Diameter | Lumber grade | | | | | |
|---|---|---|---|---|---|---|
| | FAS | SEL | 1C | 2C | 3A | 3B |
| *Inches* | *Percent* | | | | | |
| 9 | 0 | 0 | 0 | 2 | 21 | 77 |
| 10 | 0 | 0 | 2 | 6 | 22 | 70 |
| 11 | 0 | 0 | 3 | 10 | 23 | 64 |
| 12 | 0 | 0 | 5 | 14 | 24 | 57 |
| 13 | 0 | 1 | 7 | 17 | 25 | 50 |
| 14 | 0 | 1 | 10 | 20 | 25 | 44 |
| 15 | 0 | 1 | 12 | 23 | 25 | 39 |
| 16 | 1 | 1 | 15 | 25 | 25 | 33 |
| 17 | 1 | 1 | 18 | 27 | 25 | 28 |
| 18 | 1 | 2 | 21 | 29 | 24 | 23 |
| 19 | 1 | 2 | 24 | 30 | 24 | 19 |

[a]Includes black, northern red, and scarlet oaks.

Table 4.—*Green lumber yields by grade for construction and local-use class white oak sawlogs*

| Diameter | Lumber grade | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | FAS | FASIF | SEL | 1C | 2C | SW | 3A | 3B |
| *Inches* | | | | | *Percent* | | | |
| 8 | 0 | 0 | 0 | 0 | 6 | 16 | 38 | 40 |
| 9 | 0 | 0 | 0 | 0 | 9 | 18 | 37 | 36 |
| 10 | 0 | 0 | 0 | 2 | 11 | 20 | 35 | 32 |
| 11 | 0 | 0 | 0 | 5 | 13 | 21 | 33 | 28 |
| 12 | 0 | 0 | 1 | 7 | 14 | 23 | 31 | 24 |
| 13 | 0 | 0 | 1 | 9 | 16 | 24 | 29 | 21 |
| 14 | 0 | 0 | 1 | 11 | 17 | 25 | 28 | 18 |
| 15 | 0 | 0 | 0 | 13 | 18 | 27 | 26 | 16 |
| 16 | 0 | 0 | 0 | 15 | 19 | 28 | 24 | 14 |
| 17 | 0 | 1 | 0 | 16 | 19 | 29 | 22 | 13 |
| 18 | 0 | 1 | 0 | 18 | 19 | 30 | 21 | 11 |
| 19 | 0 | 1 | 0 | 19 | 20 | 31 | 19 | 10 |
| 20 | 0 | 1 | 0 | 20 | 20 | 32 | 18 | 9 |
| 21 | 0 | 1 | 0 | 21 | 19 | 33 | 16 | 10 |
| 22 | 0 | 1 | 0 | 22 | 18 | 34 | 15 | 10 |
| 23 | 0 | 1 | 0 | 22 | 18 | 34 | 14 | 11 |
| 24 | 0 | 1 | 0 | 23 | 17 | 35 | 12 | 12 |

Table 5.—*Green lumber yields by grade for construction and local-use class chestnut oak sawlogs*

| Diameter | Lumber grade | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | FAS | FASIF | SEL | 1C | 2C | SW | 3A | 3B |
| *Inches* | | | | | *Percent* | | | |
| 8 | 0 | 0 | 0 | 0 | 3 | 22 | 22 | 53 |
| 9 | 0 | 0 | 0 | 1 | 5 | 24 | 22 | 48 |
| 10 | 0 | 0 | 0 | 1 | 7 | 26 | 23 | 43 |
| 11 | 0 | 0 | 0 | 1 | 9 | 28 | 23 | 39 |
| 12 | 0 | 0 | 0 | 2 | 11 | 30 | 22 | 35 |
| 13 | 0 | 0 | 0 | 2 | 12 | 32 | 22 | 32 |
| 14 | 0 | 0 | 0 | 3 | 13 | 34 | 21 | 29 |
| 15 | 0 | 0 | 0 | 4 | 13 | 35 | 21 | 27 |
| 16 | 0 | 0 | 0 | 5 | 14 | 37 | 19 | 25 |
| 17 | 0 | 0 | 0 | 6 | 14 | 38 | 18 | 24 |
| 18 | 0 | 0 | 0 | 7 | 13 | 40 | 16 | 24 |
| 19 | 0 | 0 | 0 | 9 | 12 | 41 | 14 | 24 |
| 20 | 0 | 0 | 0 | 10 | 11 | 42 | 12 | 25 |
| 21 | 0 | 0 | 0 | 12 | 10 | 43 | 9 | 26 |
| 22 | 0 | 0 | 0 | 14 | 8 | 44 | 7 | 27 |
| 23 | 0 | 0 | 0 | 15 | 6 | 45 | 4 | 30 |

Table 6.—*Green lumber yields by grade for construction and local-use class overcup oak sawlogs*

| Diameter | Lumber grade | | | | | | |
|---|---|---|---|---|---|---|---|
| | FAS | FASIF | SEL | 1C | 2C | 3A | 3B |
| *Inches* | | | | *Percent* | | | |
| 10 | 0 | 0 | 0 | 0 | 9 | 16 | 75 |
| 11 | 0 | 0 | 0 | 2 | 13 | 18 | 67 |
| 12 | 0 | 0 | 0 | 3 | 17 | 19 | 61 |
| 13 | 0 | 0 | 0 | 5 | 20 | 21 | 54 |
| 14 | 0 | 0 | 0 | 7 | 23 | 22 | 48 |
| 15 | 0 | 0 | 0 | 8 | 26 | 22 | 44 |
| 16 | 0 | 0 | 0 | 10 | 28 | 23 | 39 |
| 17 | 0 | 0 | 0 | 12 | 29 | 23 | 36 |
| 18 | 0 | 0 | 0 | 14 | 30 | 23 | 33 |
| 19 | 0 | 0 | 0 | 16 | 31 | 23 | 30 |
| 20 | 0 | 0 | 0 | 18 | 32 | 22 | 28 |
| 21 | 0 | 0 | 0 | 20 | 31 | 22 | 27 |
| 22 | 0 | 0 | 0 | 22 | 31 | 21 | 26 |
| 23 | 0 | 0 | 0 | 25 | 30 | 19 | 26 |
| 24 | 0 | 0 | 0 | 27 | 29 | 18 | 26 |

Table 7.—*Green lumber yields by grade for construction and local-use class yellow-poplar sawlogs*

| Diameter | Lumber grade | | | | | | |
|---|---|---|---|---|---|---|---|
| | FAS | SEL | SAPS | 1C | 2A | 2B | 3C |
| *Inches* | | | | *Percent* | | | |
| 8 | 0 | 0 | 0 | 2 | 7 | 89 | 2 |
| 9 | 0 | 0 | 0 | 3 | 14 | 81 | 2 |
| 10 | 0 | 0 | 0 | 5 | 21 | 72 | 2 |
| 11 | 0 | 0 | 0 | 7 | 27 | 64 | 2 |
| 12 | 0 | 0 | 0 | 9 | 32 | 57 | 2 |
| 13 | 0 | 0 | 1 | 12 | 35 | 50 | 2 |
| 14 | 0 | 0 | 1 | 15 | 38 | 44 | 2 |
| 15 | 0 | 0 | 2 | 18 | 39 | 39 | 2 |
| 16 | 0 | 0 | 2 | 22 | 39 | 35 | 2 |
| 17 | 0 | 0 | 2 | 26 | 39 | 31 | 2 |
| 18 | 0 | 0 | 3 | 30 | 37 | 28 | 2 |
| 19 | 0 | 0 | 4 | 35 | 34 | 25 | 2 |
| 20 | 0 | 0 | 5 | 40 | 30 | 23 | 2 |

Table 8.—*Green lumber yields by grade for construction and local-use class red maple sawlogs*

| Diameter | Lumber grade | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | FAS | FASIF | SEL | 1C | 2A | 2B | 3A | 3B |
| *Inches* | | | | *Percent* | | | | |
| 8 | 0 | 0 | 0 | 1 | 1 | 56 | 0 | 42 |
| 9 | 0 | 0 | 0 | 2 | 5 | 69 | 5 | 19 |
| 10 | 0 | 0 | 0 | 2 | 8 | 75 | 11 | 4 |
| 11 | 0 | 0 | 0 | 4 | 11 | 72 | 13 | 0 |
| 12 | 0 | 0 | 0 | 6 | 13 | 65 | 15 | 1 |
| 13 | 0 | 0 | 0 | 9 | 14 | 50 | 14 | 13 |
| 14 | 0 | 0 | 0 | 12 | 14 | 28 | 11 | 35 |
| 15 | 0 | 0 | 0 | 16 | 14 | 0 | 5 | 65 |

Table 9.—*Green lumber yields by grade for construction and local-use class yellow birch sawlogs*

| Diameter | Lumber grade | | | | | | |
|---|---|---|---|---|---|---|---|
| | FAS | FASIF | SEL | 1C | 2C | 3A | 3B |
| *Inches* | | | | *Percent* | | | |
| 8 | 0 | 1 | 0 | 0 | 5 | 34 | 60 |
| 9 | 1 | 1 | 0 | 2 | 11 | 31 | 54 |
| 10 | 1 | 1 | 0 | 5 | 16 | 28 | 49 |
| 11 | 1 | 1 | 0 | 8 | 21 | 26 | 43 |
| 12 | 1 | 1 | 0 | 10 | 26 | 24 | 38 |
| 13 | 2 | 1 | 0 | 12 | 29 | 22 | 34 |
| 14 | 2 | 1 | 0 | 14 | 33 | 20 | 30 |
| 15 | 2 | 1 | 0 | 16 | 36 | 19 | 26 |
| 16 | 2 | 2 | 0 | 18 | 38 | 18 | 22 |
| 17 | 2 | 2 | 0 | 19 | 40 | 18 | 19 |
| 18 | 2 | 2 | 0 | 21 | 42 | 17 | 16 |
| 19 | 2 | 3 | 0 | 22 | 42 | 17 | 14 |
| 20 | 2 | 3 | 0 | 23 | 43 | 17 | 12 |
| 21 | 2 | 3 | 0 | 25 | 42 | 18 | 10 |
| 22 | 2 | 5 | 0 | 26 | 41 | 18 | 8 |
| 23 | 2 | 5 | 0 | 26 | 40 | 20 | 7 |
| 24 | 2 | 6 | 0 | 27 | 38 | 21 | 6 |

Table 10.—*Green lumber yields by grade for construction and local-use class paper birch sawlogs*

| Diameter | Lumber grade | | | | | |
|---|---|---|---|---|---|---|
| | FAS | SEL | 1C | 2C | 3A | 3B |
| *Inches* | | | *Percent* | | | |
| 8 | 0 | 0 | 3 | 9 | 37 | 51 |
| 9 | 0 | 1 | 3 | 13 | 38 | 45 |
| 10 | 0 | 1 | 3 | 17 | 38 | 41 |
| 11 | 0 | 1 | 4 | 20 | 37 | 38 |
| 12 | 0 | 1 | 6 | 22 | 35 | 36 |
| 13 | 0 | 1 | 9 | 24 | 31 | 35 |
| 14 | 0 | 1 | 12 | 25 | 27 | 35 |
| 15 | 0 | 1 | 16 | 25 | 21 | 37 |
| 16 | 0 | 1 | 21 | 25 | 14 | 39 |

Table 11.—*Green lumber yields by grade for construction and local-use class hickory sawlogs*

| Diameter | Lumber grade | | | |
|---|---|---|---|---|
| | FAS | 1C | 2C | 3C |
| *Inches* | | *Percent* | | |
| 8 | 0 | 0 | 26 | 74 |
| 9 | 0 | 0 | 38 | 62 |
| 10 | 0 | 0 | 47 | 53 |
| 11 | 0 | 1 | 52 | 47 |
| 12 | 0 | 3 | 55 | 42 |
| 13 | 0 | 6 | 53 | 41 |
| 14 | 0 | 10 | 49 | 41 |
| 15 | 0 | 16 | 40 | 44 |
| 16 | 0 | 22 | 29 | 49 |

Table 12.—*Green lumber yields by grade for construction and local-use class beech sawlogs*

| Diameter | Lumber grade | | | | | | |
|---|---|---|---|---|---|---|---|
| | FAS | FASIF | SEL | 1C | 2C | 3A | 3B |
| *Inches* | *Percent* | | | | | | |
| 9 | 0 | 0 | 0 | 0 | 0 | 20 | 80 |
| 10 | 0 | 0 | 0 | 0 | 4 | 25 | 71 |
| 11 | 0 | 1 | 0 | 5 | 11 | 27 | 56 |
| 12 | 0 | 3 | 0 | 9 | 17 | 28 | 43 |
| 13 | 0 | 4 | 0 | 13 | 22 | 28 | 33 |
| 14 | 0 | 5 | 1 | 16 | 26 | 28 | 24 |
| 15 | 0 | 5 | 1 | 19 | 29 | 28 | 18 |
| 16 | 0 | 6 | 1 | 21 | 31 | 28 | 13 |
| 17 | 0 | 6 | 2 | 22 | 32 | 27 | 11 |
| 18 | 0 | 5 | 2 | 23 | 32 | 27 | 11 |
| 19 | 0 | 5 | 3 | 23 | 31 | 25 | 13 |
| 20 | 0 | 4 | 4 | 23 | 29 | 24 | 16 |
| 21 | 0 | 3 | 5 | 22 | 25 | 22 | 23 |

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by David N. Larsen
and David A. Gansner

# Explaining the Forest Product Selling Behavior of Private Woodland Owners

USDA FOREST SERVICE RESEARCH PAPER NE-257
1973

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE DIRECTOR

## The Authors

DAVID N. LARSEN received his bachelor of science degree in forestry from Washington State University in 1964, a master of science degree in forest economics from Michigan State University in 1967, and a master of arts degree in regional science from the University of Pennsylvania in 1971. He joined the Northeastern Forest Experiment Station at Upper Darby, Pennsylvania, in 1967 and is a research forester in the regional production economics work unit.

DAVID A. GANSER is leader of the Northeastern Forest Experiment Station's regional production economics research work unit at Upper Darby, Pennsylvania. He received his degree in forestry from the University of Missouri in 1958, a master's degree in agricultural economics from Ohio State University in 1968, and a master's degree in regional science from the University of Pennsylvania in 1970. He has been with the USDA Forest Service since 1958.

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# Explaining the Forest Product Selling Behavior of Private Woodland Owners


## ABSTRACT

A multiple-variable screening technique, AID, was used to explain the forest-product-sales behavior of private woodland owners. Results provide a basis for policy-related inferences and suggest an optimal strategy for encouraging sales of forest products.


FARMERS, small businessmen, laborers, professionals, clerks, retirees and other private noncorporate owners collectively own about 80 percent of the commercial forest land in the 14 Northeastern States. Consequently, the decisions they make about the use of their woodlands have a major impact on the future availability of forest products and services in the region. Yet little is known about the forest-related behavior of this significant group of decision-makers. We have used a multiple-variable screening procedure to explain their forest-product-selling behavior in terms of characteristics of ownership.

## APPROACH

Two dependent variables of sales behavior and several independent variables of ownership were selected for analysis. Our data were derived from a recent study describing the characteristics, attitudes, and actions of 394 private noncorporate woodland owners in Pennsylvania *(Larsen and Gansner 1972)*.

### Variables

*Dependent variables.*—Recent sales of forest products and intent to sell forest products in the future were the dependent behavior variables. Sample owners were split on each variable. Owners who sold forest products in the past 5 years were classified as *sellers.* The rest were labeled *nonsellers.* Owners who definitely intended to sell forest products in the next 5 years were classified as *owners who plan to sell.* The rest were labeled *owners who do not plan to sell or are not certain.*

*Independent variables.*—Ownership characteristics hypothesized to reflect recent forest-product sales and sales intent were the independent variables. Twelve ownership variables were used to analyze recent forest-product sales and thirteen ownership variables were used to analyze sales intent (table 1).

Table 1.—*Statistical relationships between selected ownership characteristics and forest-product-sales behavior*

| Ownership characteristics | Chi-square significance level | |
|---|---|---|
| | Recent sales | Sales intent |
| | *Pct.* | *Pct.* |
| 1. Acreage of woodland owned | 0.1 | 0.1 |
| 2. Duration of woodland ownership | 2.0 | [a] |
| 3. Type of ownership | [a] | [a] |
| 4. Distance from residence to woodland | [a] | [a] |
| 5. Encumbered status of woodland | [a] | [a] |
| 6. Age | [a] | [a] |
| 7. Formal education | [a] | [a] |
| 8. Occupation | .1 | .5 |
| 9. Income | 1.0 | 2.0 |
| 10. Use of forest-management practices[b] | .1 | .1 |
| 11. Participation in formal government programs[b] | [a] | [a] |
| 12. Receipt of forest-management or timber-marketing information[b] | .1 | .1 |
| 13. Recent sales of forest products[b] | [c] | .1 |

[a]Not significant at the 5.0-percent level.
[b]During the past 5 years.
[c]Not applicable.

## Contingency Analysis

We used simple bivariate contingency analysis to test the relationships between the dependent variables and each of the selected ownership characteristics (table 1). Test results showed a highly significant dependence (at the 0.1-percent level) between recent product sales and four ownership characteristics: acreage of woodland owned, occupation, use of forest-management practices, and receipt of information about forest management or marketing. Income and duration of ownership were also related to recent sales, but at lower levels of significance.

Intent to sell forest products was significantly related (at the 0.1-percent level) with four ownership variables: acreage of woodland owned, use of forest-management practices, receipt of information about forest management or marketing, and recent forest-product sales. Occupation and income were also related to sales intent but at lower levels of significance.

The contingency analysis identified several variables for explaining sales behavior. However, it did not indicate what combination of ownership variables best explains sales behavior.

## Multiple Variable Analysis

What combination of ownership variables best explains recent forest-product sales and sales intent? To answer this question we turned to an iterative variance classification scheme called AID—Automatic Interaction Detector *(Sonquist and Morgan 1964)*. AID, a nonsymmetrical binary branching process, was used to subdivide the sample of woodland owners into a series of subgroups. These subgroups maximized our ability to explain forest-product-sales behavior.

The AID technique has distinct advantages over conventional multiple-regression techniques. It can accommodate classification (dummy) variables, and it requires no specification of a general linear model.

We set the following splitting constraints appropriate for our study:

1. The best split of any candidate group had to reduce the unexplained sum of squares by at least 1.0 percent of the total sum of squares (around the grand mean).
2. Each of the resultant groups of a split had to contain a minimum of 30 observations.
3. Independent variables (acreage, duration of ownership, age, education, and income) that were expected to have a monotonic effect on each dependent variable were assigned a monotonic splitting constraint.

# RESULTS

Two *dependent* behavior variables were subjected to AID analysis. The output of each analysis is presented as a tree of binary splits (fig. 1 and fig. 2). A detailed analysis of the development of one of these trees—the one used to explain recent forest-product sales activity—helps to understand and interpret the study results.

Group 1 in figure 1 represents the total sample of 394 woodland owners. Twenty

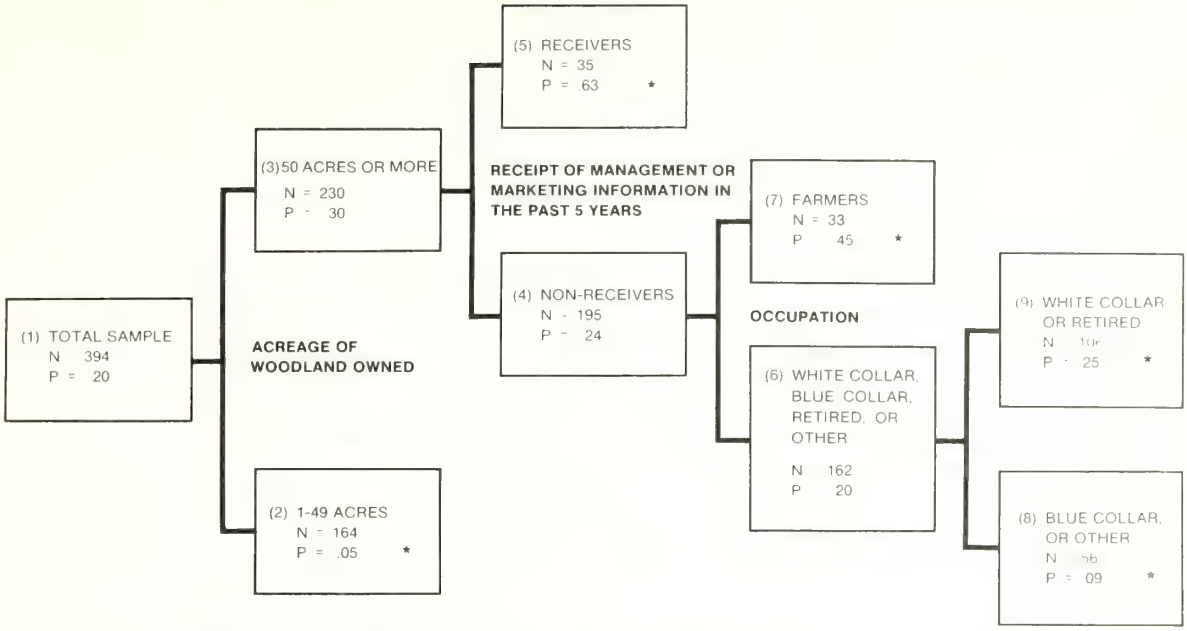
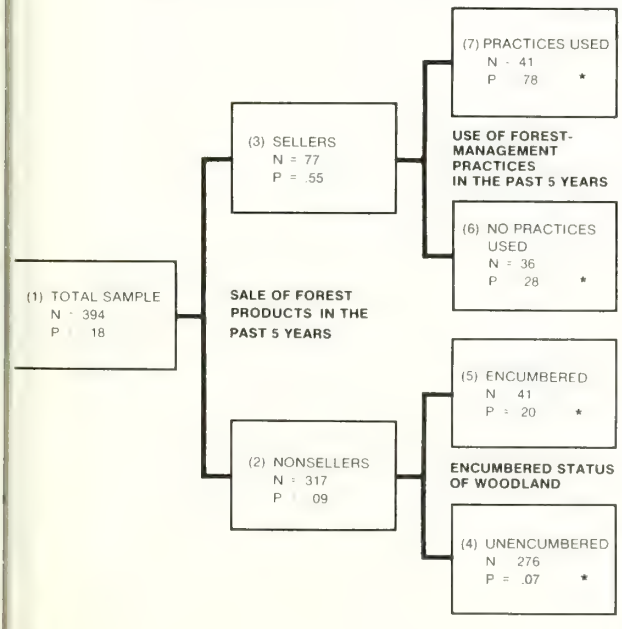



Figure 1.—Variables explaining recent sales of forest products. N = group size; P = proportion of owners in a group who sold forest products during the past 5 years; and * = final group. "Other occupations" include service workers, housewives, and disabled and unemployed individuals.

Figure 2.—Variables explaining intent to sell forest products in the future. N = group size; P = proportion of owners in a group who plan to sell forest products in the next 5 years; and * = final group. "Encumbered woodlands" are mortgaged, used for collateral, or leased.




percent of these owners sold forest products in the past 5 years. Our goal was to find the combination of variables that best explains recent product sales. Group 1 was split into two groups on the variable that maximizes the reduction in the unexplained sum of squares. The best variable for splitting group 1 was *acreage of woodland owned.*

The resulting groups were group 2, *owners of 1 to 49 acres of woodland;* and group 3, *owners of 50 acres or more of woodland.* Similarly, group 3 was divided into group 4, *non-receivers;* and group 5, *receivers* of information about forest-product management or marketing during the past 5 years. The same procedure was followed to split group 4, and so on.

*N* denotes the number of sample owners in each group, and *P* is the proportion of owners in that group who sold forest products in the past 5 years. A group that cannot be split further (see three splitting constraints) is marked with an asterisk and constitutes a final group. Group 7, for example constitutes a final group of 33 owners. Each member of this

group is a farmer who owns 50 acres or more of woodland and has not received information about management or marketing in the past 5 years. Forty-five percent of these individuals sold forest products.

Key groups for explaining owner behavior are those with the highest and lowest *P* values in each tree of binary splits. These groups characterize behavioral extremes. Groups 2 and 5 (fig. 1) are good examples. According to our analysis, forest-product sellers were least prevalent among members of group 2 and most prevalent among members of group 5.

### Recent Forest Product Sales

Twenty percent of the original sample of 394 woodland owners sold forest products during the past 5 years (group 1, fig. 1). Splitting the sample on two key variables substantially improved, our ability to explain their recent sales behavior. If an individual owns less than 50 acres of woodland, chances are very slim that he sold forest products during the past 5 years. Only 1 in 20 of these small tract owners did (group 2, fig. 1). If, on the other hand, he owns at least 50 acres of woodland and has received information about the management and marketing of forest products in the recent past, chances are relatively good (63 out of 100) that he sold forest products (group 5, fig. 1).

Though these results do not prove cause and effect relationships, they do provide a basis for policy-related inferences. It appears that owners of large timber tracts are more willing and better able to satisfy current demands for forest commodities. One way to effectively stimulate the selling activity of these owners is to provide more of them with information about the management and marketing of forest products.

### Intent to Sell Forest Products in Future

Eighteen percent of the original sample of owners definitely intend to sell forest products in the next 5 years (group 1, fig. 2). The rest either do not plan sales or are not certain of their selling plans.

The inclination to sell is greatest among those individuals who have sold forest products and have practiced some form of forest management on their woodland in the recent past. Nearly four-fifths of these owners plan to make future sales (group 7, fig. 2). Owners who have not experienced recent sales and whose woodlands are not encumbered (not mortgaged, used for collateral, or leased) tend to have very little interest in future sales (group 4, fig. 2).

The highly significant relationship between past selling behavior and future sales intent was surprising. Apparently many of the owners who recently sold forest products considered it a rewarding experience—so much so that they fully intend to try it again. Recent use of forest-management practices apparently strengthens the urge to make future sales and perhaps reflects a desire to recover funds invested in forestry.

## IMPLICATIONS

Our study has demonstrated the usefulness of a multiple-variable screening technique, AID, to explain the behavior of an important group of decision-makers. Results provide a basis for policy-related inferences and indicate optimal strategies for program orientation.

Suppose, for example, our objective were to encourage the sale of forest products from privately owned woodlands in Pennsylvania. The behavior patterns revealed by this study suggest that we should provide information about the management and marketing of forest products to more owners of large wooded tracts (50 acres or more). Owners who have sold forest products and practiced some form of forest management on their woodlands in the recent past should prove most receptive to sales promotion.

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# THE COURSE OF GROWTH RESPONSE IN RELEASED WHITE SPRUCE-- 10-Year Results

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by Robert M. Frank

USDA FOREST SERVICE RESEARCH PAPER NE-258
1973

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

## THE AUTHOR

ROBERT M. FRANK, research forester, received a bachelor of science degree in forestry from the Pennsylvania State University in 1954 and a master of forestry degree in forest products from the same university in 1956. He joined the USDA Forest Service in 1957 and has served in economics research, forest survey, and mine-spoil revegetation projects of the Northeastern Forest Experiment Station. Since 1963 he has been on the staff of the station's spruce-fir silviculture project at Orono, Maine.

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# THE COURSE OF GROWTH RESPONSE IN RELEASED WHITE SPRUCE--10-Year Results


**Abstract**

Weekly bole measurements at 4.5 feet in height were made on individual codominant white spruce trees released on one, two, three, and four sides, and on untreated controls.

Results showed that after 10 years annual circumference growth was still significantly related to the degree of release. The growth trend was established the first year but significant differences in annual growth were not evident until the third year. The growth rate reached a maximum during the ninth year. Trees with three and four sides released outgrew controls and trees with one and two sides released by a 2 to 1 ratio.

Seasonal growth usually started around May 10, peaked during the second week in June, and ceased around August 20. Trees released on three or four sides appeared to start growing earlier and cease growing several days later than the other trees. The length of the growing season ranged from 100 to 115 days.


## AMOUNT OF RELEASE IS IMPORTANT

HOW MUCH additional growing space does a potential crop tree spruce need to benefit from thinning? On how many sides should such a tree be released? How soon and for how many years will the effects of release be evident? Questions like these must be answered before timber stands can be managed intensively with conscious silvicultural treatment. A knowledge of the spatial requirements of the individual tree is necessary before maximum merchantable growth can be obtained in overstocked spruce-fir stands.

Timber-marking rules for uneven-aged stands and marking rules for intermediate cultural treatments in even-aged stands are not complete unless they contain spacing recommendations. And the length of crop rotation cannot be reduced until crop trees are groomed to merchantable size in fewer years.

Therefore we undertook a study in Maine to determine the level of release needed to produce and maintain significant growth response in pole-size white spruce. I concluded that release on more than two sides is required. It was also determined that the number of days that a tree grows during the growing season is affected by release.

## THE STUDY

The study was begun in 1961 in a white spruce-balsam fir stand on the Penobscot Experimental Forest located 8 miles northeast of Bangor, Maine (44° 52′ N.; 68° 39′ W.), at an elevation of approximately 100 feet. The topography is flat to very gently sloping. The

soils in the one-acre study area vary from silt loam to some glacial till. Drainage ranges from moderately good to poor. Precipitation during the growing season usually totals about 12 inches, and is evenly distributed. Mean temperature ranges from 54°F., in May to 68°F. in July.

The trees are pole-sized, even-aged, and became established around 1890. Dominant and codominant trees averaged about 50 feet tall with an average crown diameter of 10 feet. The stand contained about 190 square feet of basal area in trees in the intermediate and better crown positions. White spruce [*Picea glauca* (Moench) Voss] and balsam fir [*Abies balsamea* (L.) Mill.] were about equally represented (fig. 1), with a scattering of associated species that accounted for less than 10 percent of the basal area.

Figure 1.—The study area is an even-aged stand of pole-sized white spruce and balsam fir.

## RELEASING METHOD

Twenty-five codominant white spruce trees between 5.0 and 6.7 inches in diameter at 4.5 feet were selected for study. Sample trees were selected at random and far enough apart so that crown release treatments did not interfere with each other. There were five trees in each of five groups:

| | |
|---|---|
| Control | — no crown release. |
| Crown released on one side | — adjacent trees removed from east quadrant. |
| Crown released on two sides | — adjacent trees removed from east and south quadrants. |
| Crown released on three sides | — adjacent trees removed from east, south, and west quadrants. |
| Crown released on four sides | — all adjacent trees removed. |

Each treatment consisted of removing adjacent trees to a distance approximating the average crown diameter of the sample tree. This distance, measured from crown to crown, usually ranged between 8 feet and 10 feet. In most quadrants only one or two trees were removed; in others, three or more trees were removed. Felled trees were bucked, limbed, topped, and left in place. There were no other activities on the site for the duration of the study.

## MEASUREMENTS

Dendrometer bands[1] were installed at breast height (4.5 feet) on each sample tree (fig. 2). Each tree was assigned a number and tagged.

Dendrometer readings were recorded to the nearest 1/100th inch of circumference. Observations were taken weekly from before diameter growth started in the spring to late summer or early fall, when three successive weekly readings failed to show any increase

[1]Liming, F. G. 1957. HOMEMADE DENDROMETERS. J. Forest. 55:575-577.

Figure 2. — Dendrometer band in place on a tree with vernier scale being positioned for a reading.

in circumference. In most years, measurements were taken from the latter part of April to the early part of October.

## DATA ANALYSIS

Circumference growth was charted for each group of trees for each year. Comparisons were made by analysis of variance to determine whether significant differences developed (table 1).

Table 1.—*Mean annual circumference increase by treatment, 1961 through 1970*

| Year | Control | Released on | | | |
|---|---|---|---|---|---|
| | | 1 Side | 2 Sides | 3 Sides | 4 Sides |
| | | | *Inches* | | |
| 1961 | 0.158[a] | 0.178 | 0.136 | 0.238 | 0.212 |
| 1962 | .194 | .196 | .168 | .280 | .298 |
| 1963 | .220 | .212 | .206 | .368 | .438 |
| 1964 | .190 | .224 | .214 | .408 | .524 |
| 1965 | .202 | .226 | .228 | .420 | .450 |
| 1966 | .170 | .232 | .208 | .374 | .426 |
| 1967 | .234 | .244 | .232 | .422 | .482 |
| 1968 | .246 | .296 | .324 | .480 | .560 |
| 1969 | .326 | .322 | .372 | .622 | .580 |
| 1970 | .274 | .282 | .338 | .500 | .440 |
| Mean annual increase | 0.221 | 0.241 | 0.243 | 0.411 | 0.441 |

[a]Means not underscored by the same line are significantly different at the 5 percent level.

## RESULTS AND DISCUSSION

### Stand Development

Stem analyses of the two sample trees that died after the ninth year of observation gave insight into stand structure, both past and present. Plotted data indicate that excessive numbers of trees were present from the establishment of the stand (fig. 3). Overstocking is suggested by d.b.h. and growth rings per inch and also by the slow growth of the sectioned trees:

| | *Tree #1* | *Tree #2* |
|---|---|---|
| Age, yrs. | 87 | 77 |
| D.b.h., inches | 7.5 | 6.4 |
| Height, ft. | 51.0 | 50.9 |
| Growth rings per inch | 23.2 | 24.1 |
| Years to reach: | | |
| 4.5 ft. | 20 | 12 |
| 10.0 ft. | 30 | 21 |
| 20.0 ft. | 43 | 36 |
| 30.0 ft. | 60 | 47 |
| 40.0 ft. | 71 | 58 |
| 50.0 ft. | 85 | 75 |

### Circumference Growth Response

Mean annual circumference growth for the five trees in each treatment group was plotted by date of reading for each growing season. A sigmoid curve, the characteristic curve of growth, resulted when the data for all 10 years and all sample trees were combined. It shows the percentage of annual growth that had occurred by various dates during the growing season (fig. 4).

Similar curves developed from data from individual treatments failed to show much difference. There was an indication however, that trees released on three or more sides achieved a specified percentage of growth one to three days earlier than the control trees.

A difference in growth response related to the degree of release was noticeable the first year after thinning, continued during the second year, and became statistically significant in the third year. The difference continued, except for a slight disruption midway through the study, probably caused by less than normal rainfall, peaked in the ninth year, and was still evident at the termination of observations after the tenth year (fig. 5).

The controls and the trees released on one or two sides grew only one-half as much as

Figure 3.—Height/age relationships of two white spruce trees.

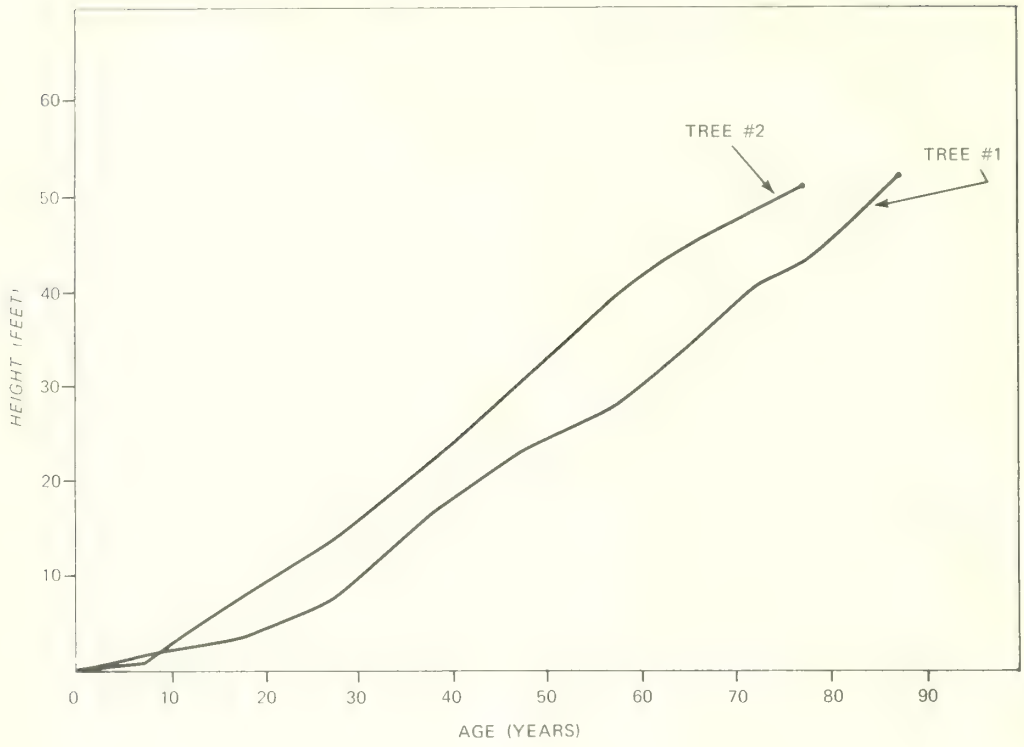



Figure 4.—Percentage of mean annual circumference growth that had occurred by various dates (All treatments and all years combined).

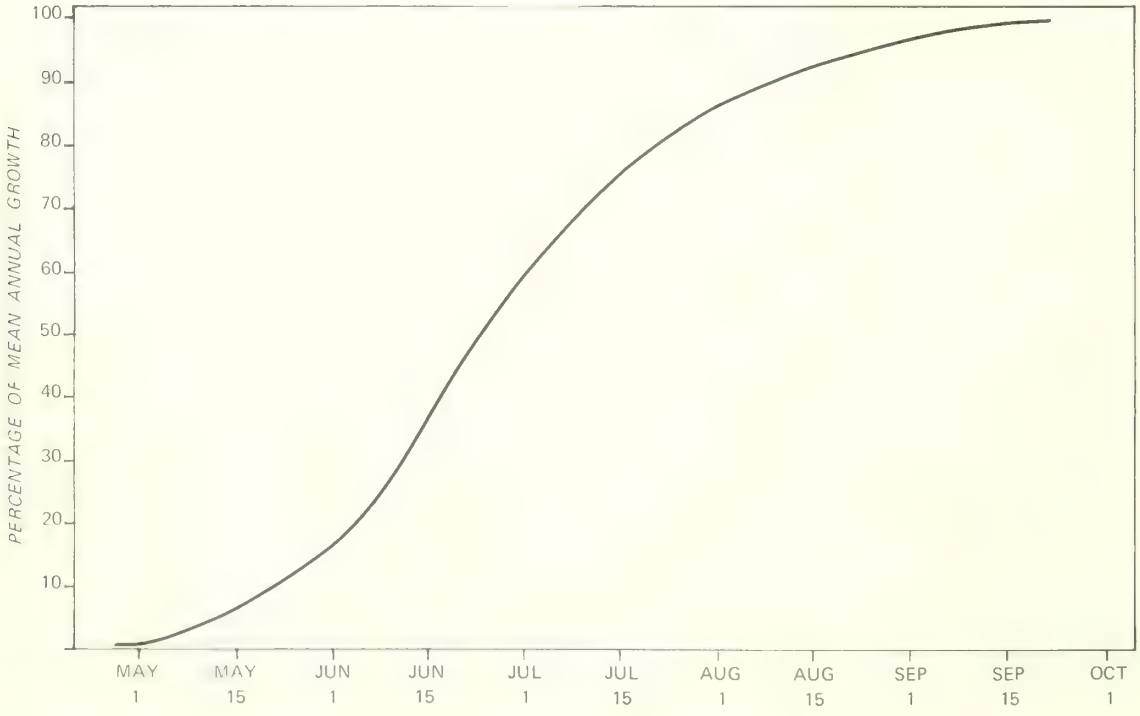
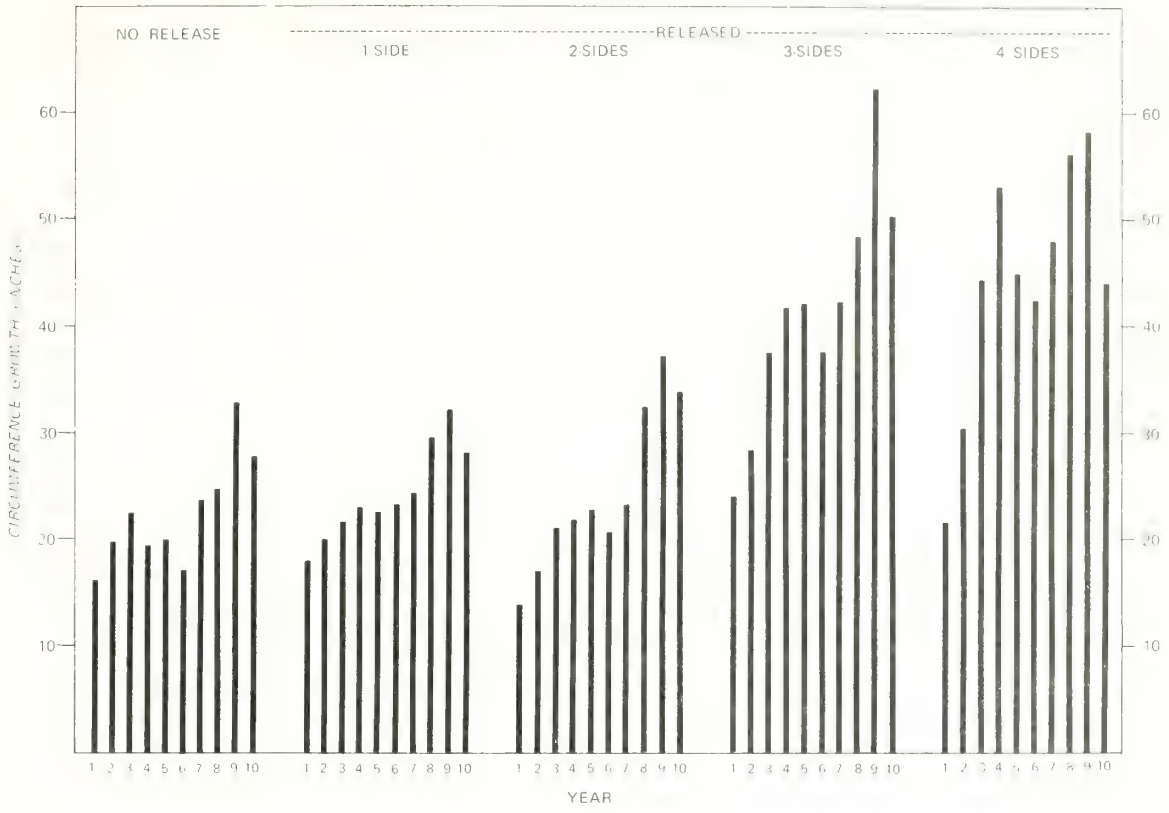


Figure 5.—Mean annual circumference growth by treatment.




the trees released on three or four sides (fig. 6). Cumulative growth curves were developed by summing the growth responses of all trees in each treatment group.

Up to the time of thinning, the mean number of annual growth rings per inch of diameter in sample trees ranged between 25 and 30. During the 10-year period after thinning, the mean numbers of rings per inch were:

| | *Mean number of rings per inch* |
|---|---|
| Controls | 28 |
| Released one side | 26 |
| Released two sides | 26 |
| Released three sides | 15 |
| Released four sides | 14 |

## The Distribution of Growth

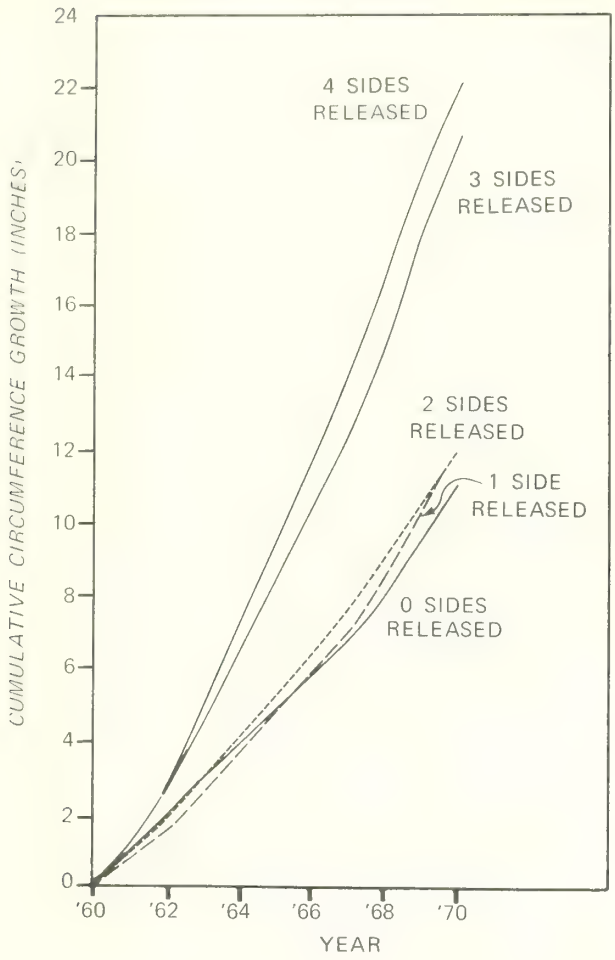
During the 10-year study period, the first evidence of circumference growth appeared between the first week in May and the first week in June. The most common date was around May 10.

Growth was usually most rapid during the second week in June, when it approached 2 percent a day. The seasonal rate of growth for various periods is shown by the slope of the curve in figure 4. As the growth rate accelerates in the spring, the slope becomes steeper; it remains relatively steep until mid-July; then rapidly flattens out in late August and September, when seasonal growth finally ceases.

Growth was one-half completed by the fourth week in June; almost two-thirds completed by the fourth of July; and 85 percent completed by August 1.

The controls and trees released on one or two sides commonly ceased growing around August 20, while the trees released on three or four sides appeared to grow for an additional one to two weeks. The relatively free-growing position of the more fully released trees may have given them greater access to light and less competition for available moisture, and thus extended their growing season.

Figure 6.—Mean cumulative circumference growth by treatment for all trees, 1961 to 1970.




But growth at the end of the growing season is very slow and contributes an insignificant amount to annual growth.

The length of the growing season, derived from average dates when growth began and ended, ranged from about 100 to 115 days. The frost-free season is 140 to 145 days.

## CONCLUSIONS

Ten years of observations indicate that neglected white spruce, 70 to 75 years old, will respond to release. Clearing around individual crop trees must be done on at least three and preferably four sides for significant benefits. In spruce-fir stands on wet and steep sites, no more than 10 to 20 percent of the total volume should be removed in a single operation. On well drained sites, up to 50 percent can be removed. And older stands should not be logged as heavily as younger stands.[2] Excessive removals can result in wind damage.

How many crop trees per acre to release will depend on the management objectives of the landowner or manager.

For a thinning to be effective, the minimum distance between the crown of a selected crop tree and the crowns of competitors on each thinned side should be equal to the crown diameter of the tree being released. This was the spacing used in this study.

■

[2]Westveld, Marinus. 1953. ECOLOGY AND SILVICULTURE OF SPRUCE-FIR FORESTS OF EASTERN NORTH AMERICA. J. Forest. 51:422-430.

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# DEFORESTATION EFFECTS
## on soil moisture, streamflow, and water balance in the central Appalachians

by James H. Patric

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

## The Author

JAMES H. PATRIC is a research forester in the Northeastern Forest Experiment Station. He received his bachelor of science degree in forestry from the University of Connecticut in 1947 and his master of forestry degree from Harvard University in 1957. He served as research project leader in forest hydrology at the Timber and Watershed Laboratory at Parsons, West Virginia, and is currently doing advanced research in lysimetry as a Bullard Fellow at Harvard University.

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# DEFORESTATION EFFECTS on soil moisture, streamflow, and water balance in the central Appalachians


## ABSTRACT

Soil moisture, precipitation, and streamflow were measured on three watersheds in West Virginia, two deforested and one forested. Water content of barren soil always exceeded that of forest soil throughout the growing season and especially in dry weather. Streamflow increased 10 inches annually on the watersheds that were cleared, most of the increase occurring between July and October. Higher soil moisture was accompanied by large instantaneous peak flows during small storms in the growing season but this peak effect was minor in large storms and in all storms during the dormant season. With precipitation, streamflow, interception losses, and soil-moisture change estimated to comparable levels of precision, the water balance equation was solved for transpiration with sufficient sensitivity to demonstrate the effects of tree leaf growth. After tree leaves were fully grown, calculated evaporative losses from the forested watershed somewhat exceeded potential rates as long as unmeasured runoff (leakage) was disregarded. With all components of the water balance quantified, including leakage, estimated soil-moisture loss by transpiration was at rates close to potential. Estimated leakage seemed consistent with observed stream behavior.


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SMALL GAGED WATERSHEDS are frequently proposed as ideal sites for water-balance studies. Incoming precipitation and streamflow may be estimated to accuracies of ± 5 percent (*Hornbeck 1965*). The difference, precipitation minus runoff, is often equated to evaporative loss, but this reasoning is valid only if all liquid water draining from the basin is measured. Small watersheds are especially useful in forest water-balance studies because they provide real-life tree growing conditions without the confounding effects on tree growth that plague lysimetry (*Patric 1961*) or the boundary problems inherent in plot studies. However, soil-moisture variation, a key factor in computing the complete water balance on small watersheds, has proven hard to evaluate.

At least three approaches have been devised that appeared to obviate the need to quantify soil-moisture loss from forested land. Several "bookkeeping" methods were attempted (*Reinhart 1964*). Earlier forest studies showed that soil moisture in humid climates usually returns to "field capacity" during the dormant season (*Helvey and Hewlett 1962*), prompting many to disregard soil-moisture variation when computing annual water balances. But this approach is invalid in arid climates, where dormant-season precipitation is frequently insufficient to replenish soil moisture lost during the growing-season. Thornthwaite's (*1948*) concept of potential evapotranspiration allows long-term estimates of evaporative loss to be based almost entirely on climatic parameters, which are far more easily estimated than soil-moisture loss. Unfortunately, considerable uncertainty is associated with all three methods, particularly when only short-term data are available for calculating forest water balances.

The neutron-moderation technique currently offers a good approach to obtaining highly reproducible soil-moisture data from forest land. Properly installed access tubes minimally alter hydrologic performance in the

surrounding soil and nearby tree roots. The measurement obtained is an integrated value for water content in about 1 cubic foot of soil. There are, of course, physical and economic limits on the numbers of tubes that can be installed, the depths to which they are inserted, and the frequency of soil-moisture measurements. Nevertheless, the technique affords easy, rapid, accurate, and relatively inexpensive collection of data on moisture variation in forest soils.

The objective of my study was to determine deforestation effects on soil moisture, streamflow, and water balance.

## STUDY AREA AND METHODS

The study watersheds are located on the Fernow Experimental Forest near Parsons, West Virginia, on mountain land ranging from 2 to 3 thousand feet in elevation above sea level. The climate is perhumid (*Thornthwaite 1948*) with an average annual rainfall of 57 inches, more than twice the 22-inch average annual evaporative potential (*Patric and Goswami 1968*). Potential evapotranspiration for periods between soil-moisture readings was estimated by multiplying published pan evaporation for Parsons (*U. S. Environmental Data Service 1968 and 1969*) by the coefficient 0.78 developed by Troendle and Phillips (*1970*). The growing season is roughly May through September, with an average frost-free season of 145 days. Tree leaves emerge late in April, are fully grown by 1 June, and begin to fall in early October. About 95 percent of the tree roots are found in the upper 3 feet of soil. All the experimental watersheds were completely forested until 1964 with uneven-aged stands of hardwood species; volumes ranged from 7 to 12 MBF per acre.

Calvin soils—reddish-brown, moderately deep upland inceptisols weathered from sandstone and acid red shale—predominate on the experimental watersheds. They are well drained, moderately permeable, and strongly acid. Their natural fertility is moderate to low. Their depth to bedrock averages 32 inches, ranging from 22 to 47 inches. Subsoil texture ranges from loam to silty clay loam with silt loam most common. These soils have been described in detail by Losche and Beverage (*1967*).

Precipitation on the Fernow Experimental Forest is sampled by 14 recording and standard rain gages. Streamflow from each watershed is measured in 120° V-notch weirs. Streamflow data are processed using the program described by Hibbert and Cunningham (*1967*).

The watershed treatments have been described in detail by Patric and Reinhart (*1971*). Watersheds 6 (55 acres) and 7 (58 acres) had been completely deforested by 1967 and were maintained nearly barren thereafter by intensive use of herbicides (*Patric and Campbell 1970*). Careful logging left the forest litter relatively intact on these barren watersheds, mineral soil was seldom exposed, and overland flow was a negligible component of stormflow (*Hornbeck 1968*). Logging slash and the little revegetation not killed by herbicides provided some ground cover throughout the experiment. Herbicide application ceased in August 1969; and a dense cover of herbs, grass, weeds, tree sprouts, and seedlings has since revegetated these catchments. Watershed 4 (95 acres) remained fully forested and served as an untreated control throughout the experiment.

Twenty-five aluminum access tubes were installed at random locations on each experimental watershed. A Troxler[1] probe and scaler provided data on soil moisture content at sampling positions 6 inches below the soil surface and at 12-inch intervals thereafter to depths as much as 8 feet. The 6-inch readings were not corrected for soil-air interface effects. More than 5,200 soil-moisture readings were obtained and computer processed, using the Popham-Ursic (*1968*) program.

Soil-moisture readings were planned at 2-week intervals during the growing season, but weather and competing work often forced deviation from this schedule. A few dormant season readings were taken after prolonged rain to establish maximum soil-water content.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not consititute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

## RESULTS

### Deforestation Effects on Soil Moisture

After the first year of soil-moisture measurement, we concluded that water content below 2 feet remained virtually constant on the barren watersheds. Thereafter, we made soil-moisture measurements in the top 2 feet of soil on these watersheds although measurement to full access tube depth continued on the forested watershed.

The greatest fluctuation of water content always occurred in the top 2 feet. Soil-water content fluctuated more widely in forested than in barren soils (table 1), moisture in the barren soils remaining within 1 inch of the 8-inch field capacity observed by Troendle (*1970*). Although the total rainfall during the 1968 growing season was almost identical to that of the 1969 growing season (about 26 inches), its distribution was different and relatively long rainless spells caused drier soils in 1968.

Two or sometimes 3 days were needed to sample soil moisture in all 75 access tubes. Each date listed in table 1 represents, as nearly as possible, the mid-date of the sampling period. Rainfall presented a similar tabulation problem. For simplicity, the precipitation that fell on watershed 4 was listed; the rainfall on watersheds 6 and 7 varied little from these tabulated amounts.

The last two values in table 1 illustrate the interpretive problems that weather caused. A last reading for the growing season (9 October 1969) was obtained during dry weather on watersheds 4 and 6, but heavy rain fell before corresponding data were taken on watershed 7. The opposite occurred in the spring (13 May 1970), when soil moisture on watershed 7 was measured in dry weather but heavy rain fell before corresponding data were obtained on watersheds 4 and 6. The result is a spurious indication of an over-winter decrease of soil moisture on watershed 7 while the others gained small amounts of water.

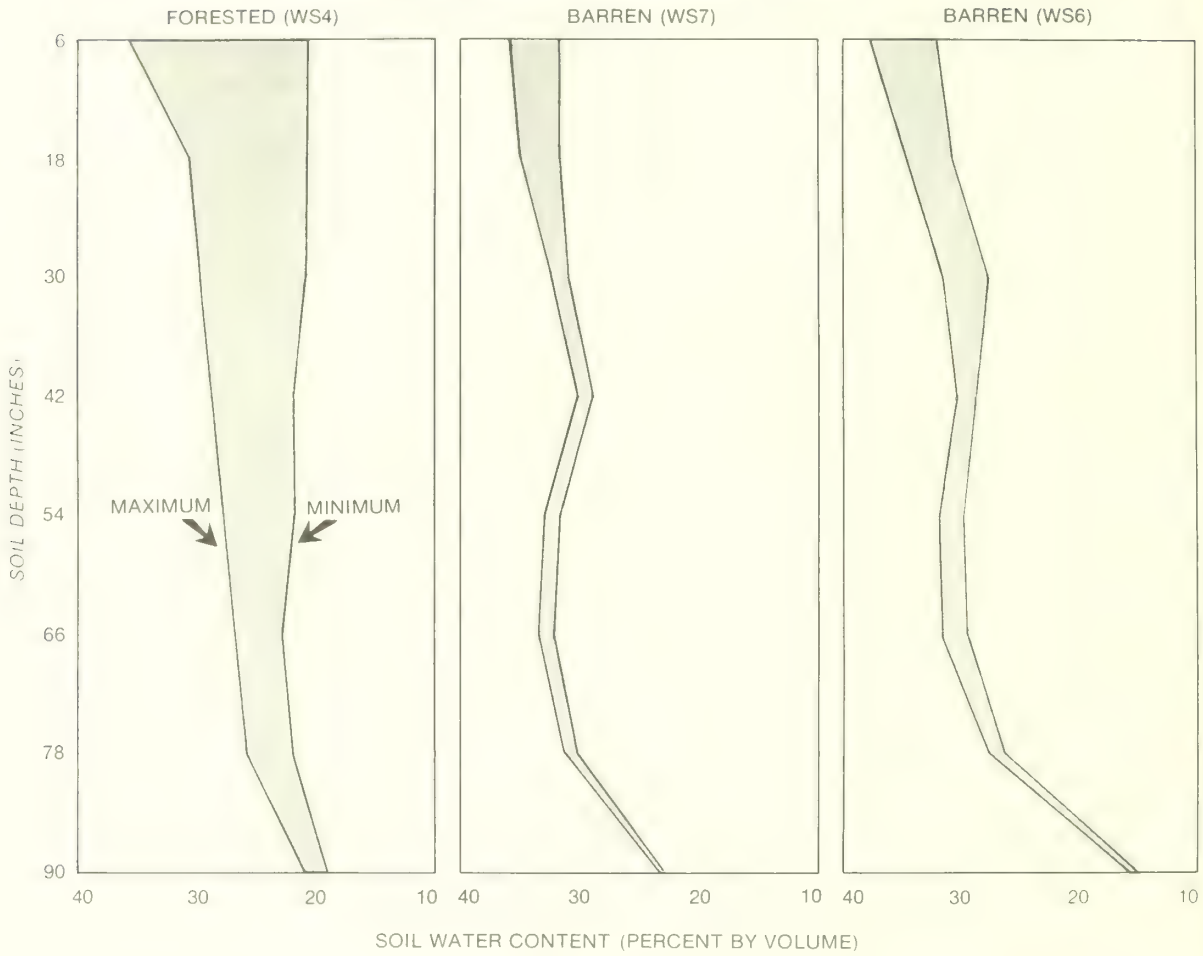
Figure 1 shows the range of soil moisture during 1968 on the three watersheds. Data were used from the six deepest access tubes on each watershed and the highest reading for each depth in any tube was plotted. The minimum readings were recorded in the same way; the width of the shaded band shows the range between observed maxima and minima. The moisture content of the soil was highest during winter and spring, lowest between June and September. As the growing season progressed,

Table 1.—Precipitation and water content in the top 2 feet of soil on the experimental watersheds, in inches

[Mean and standard deviation for 25 access tubes on each watershed]

| Date | Rain since previous measurement | Soil water content | | |
|---|---|---|---|---|
| | | Forested (WS 4) | Barren (WS 6) | Barren (WS 7) |
| 1 June 68 | — | 7.7±0.6 | 8.5±0.8 | 8.0±0.8 |
| 13 June 68 | 0.55 | 5.6±0.8 | 7.4±0.7 | 7.0±0.7 |
| 24 July 68 | 3.00 | 5.4±0.9 | 7.7±0.9 | 7.7±0.9 |
| 14 Aug 68 | 6.79 | 7.2±0.8 | 7.9±0.9 | 7.9±0.8 |
| 5 Sept 68 | .90 | 5.7±0.9 | — | — |
| 17 Sept 68 | 3.18 | 6.8±0.9 | 7.7±0.9 | 8.0±0.7 |
| 8 Oct 68 | .29 | 5.6±0.9 | 7.9±0.9 | 8.0±0.8 |
| 3 Dec 68 | 9.13 | 7.7±0.8 | — | — |
| 2 May 69 | 25.16 | 8.0±0.8 | 7.5±0.8 | 7.9±0.7 |
| 16 May 69 | 2.45 | 8.0±0.8 | — | — |
| 22 May 69 | 2.57 | 7.4±1.1 | 7.2±0.9 | 7.6±0.8 |
| 5 June 69 | .42 | 6.7±0.8 | 7.1±0.9 | 7.1±0.8 |
| 2 July 69 | 3.51 | 6.7±1.0 | 7.4±0.9 | 7.5±0.8 |
| 16 July 69 | 2.88 | 7.5±0.9 | 7.4±0.8 | 7.6±0.7 |
| 31 July 69 | 2.69 | 7.1±1.1 | 7.6±0.8 | 7.6±0.8 |
| 9 Oct 69 | 15.11 | 7.5±0.7 | 7.6±0.8 | 8.1±0.8 |
| 13 May 70 | 29.33 | 7.8±0.9 | 7.9±0.8 | 6.8±1.0 |

Figure 1.—Maximum variation in soil water content observed on the experimental watersheds in 1968.




tree roots on the forested watershed took moisture from the surface soils, then from deeper soils during the periods of below-average rainfall in June (2.2 inches) and July (3.8 inches). On barren soils, even the below-average rainfall was more than enough to replace the moisture lost by evaporation. Although watershed 6 seems to have lost more moisture than watershed 7, analysis of variance did not show the differences to be significant at the .05 level. A similar comparison of the same watersheds in 1969 showed a narrower range because evenly distributed rainfall replaced soil-moisture losses sooner.

There was so much variation among the sampling sites that no consistent influence of slope position (ridge, mid-slope, or channel) on soil-moisture loss could be shown. The effects of slope on the water content of barren soil were even smaller and less consistent than on forest soil.

Soil-moisture sampling to 1 percent of the watershed mean clearly exceeded our capability (table 2). However, 25 tubes provided precision within 5 percent of the watershed mean; it was achieved at all depths in moist soil and at depths to 4 or more feet in drier soils. Under these conditions, soil-moisture data were comparable in precision with precipitation and streamflow data as measured on the Fernow Experimental Forest.

Water contents for the 6-, 18-, and 30-inch sampling depths at the driest sites were applied to moisture-release curves (*Troendle 1970*), to estimate soil-water potential. The lowest potentials in 1968 developed at the 6-

Table 2.—Number of neutron probe access tubes needed to sample watershed soil moisture to specified levels of precision at specified soil depths

| Soil depth (inches) | Desired half width of 95% confidence interval | | | | | |
|---|---|---|---|---|---|---|
| | Moist soil[a] | | | Dry soil[b] | | |
| | 1% | 2.5% | 5% | 1% | 2.5% | 5% |
| 6 | 502 | 91 | 22 | 1,535 | 192 | 50 |
| 18 | 451 | 68 | 17 | 991 | 142 | 36 |
| 30 | 412 | 68 | 17 | 792 | 123 | 31 |
| 42 | 538 | 84 | 21 | 705 | 110 | 27 |
| 54 | 390 | 63 | 16 | 346 | 55 | 14 |
| 66 | 424 | 68 | 17 | 323 | 51 | 13 |

[a]Highest soil-moisture content, measured on May 2, 1969.
[b]Lowest soil-moisture content, measured on July 2, 1969.

inch level on forested watershed 4, ranging from —12 bars on ridges to —5 bars near streams. Water-potential values increased sharply with soil depth, never exceeding —2 bars at the 30-inch depth. This amount of drying was measured after 4 inches of water had been lost from ridgetop soils; had these soils dried to a water potential of —15 bars throughout their 4-foot depth, over 6 inches of rain would have been needed to restore the wetness observed in the springtime. In 1969, when summer rainfall was more evenly distributed, soil-water potential never fell below —10 and —0.9 bars at the driest sampling sites in ridge and channel soils, respectively.

At the 6-inch depth and below, water potentials never fell below —0.5 bars on the barren watersheds. Nevertheless, the top inch or so of soil became hot and powder-dry in summer. This dust mulch apparently combined with remnants of the organic forest soil layers to restrict soil drying almost entirely to the surface layers.

## Deforestation Effects on Streamflow

During the 3 years that watersheds 6 and 7 were kept barren, average annual streamflow was 10 inches greater than it would have been had the watersheds remained fully forested. Most of the increase was in the growing season (table 3). A low rainfall trend, especially low during the mid-60's, continued through the years 1967-69. Had rainfall been more abundant and vegetation control more complete, growing-season streamflow increases might have been larger.

The increases in streamflow for each month from July through October were significant at the .05 level, although irregular rainfall caused great year-to-year variation among these increases. But when the monthly increases for watershed 6 and 7 were averaged, using data from 1967 through 1969, they seemed much more closely related to evaporation than to precipitation (fig. 2). There was, however, about a 2-month lag between the rise and fall of evaporation and the apparent response by streamflow.

Rain absorbed into already moist soils of the barren watersheds maintained the streams from these watersheds at consistently higher levels than had prevailed under the original forest vegetation. Figure 3 shows, by cumulative frequency curves, the percentage of the time that the flow equalled or exceeded specified rates. Flows greater than 5.0 $ft^3$ $sec^{-1}$

Table 3.—Estimates of streamflow increase on barren watersheds,[a] in inches

| Year | Watershed | Growing season (May-October) | Dormant season (November-April) | Annual |
|---|---|---|---|---|
| 1967 | 6 | 8.9* | 0.6 | 9.5* |
| | 7 | 8.6* | 1.3* | 9.9* |
| 1968 | 6 | 7.9* | 2.3* | 10.2* |
| | 7 | 7.5* | 2.8* | 10.3* |
| 1969 | 6 | 9.0* | 1.5* | 10.5* |
| | 7 | 8.6* | .8 | 9.4* |

[a]Derived from regression on measured flow from the forested catchment, based on pretreatment calibration period.
*Significant at the .05 level.

Figure 2.—Effects of deforestation on monthly streamflow. Each plotted point is the 3-year average monthly value for watersheds 6 and 7.

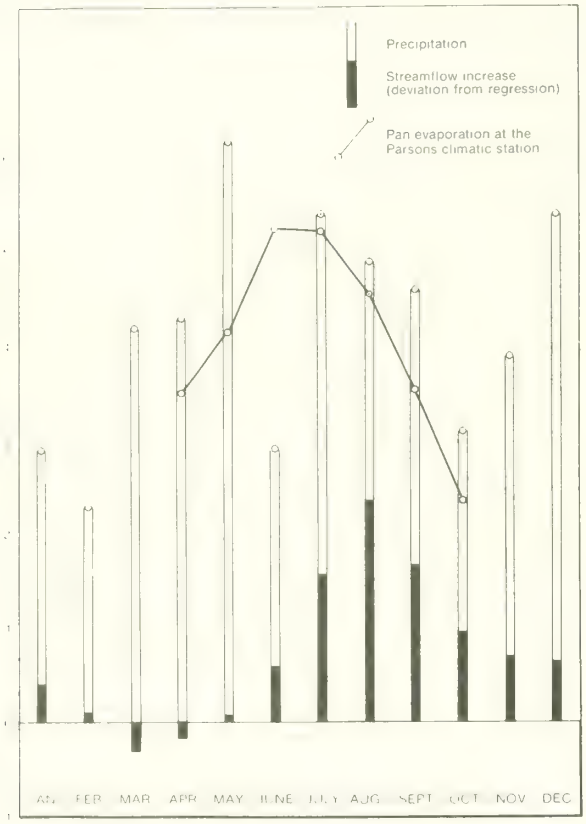
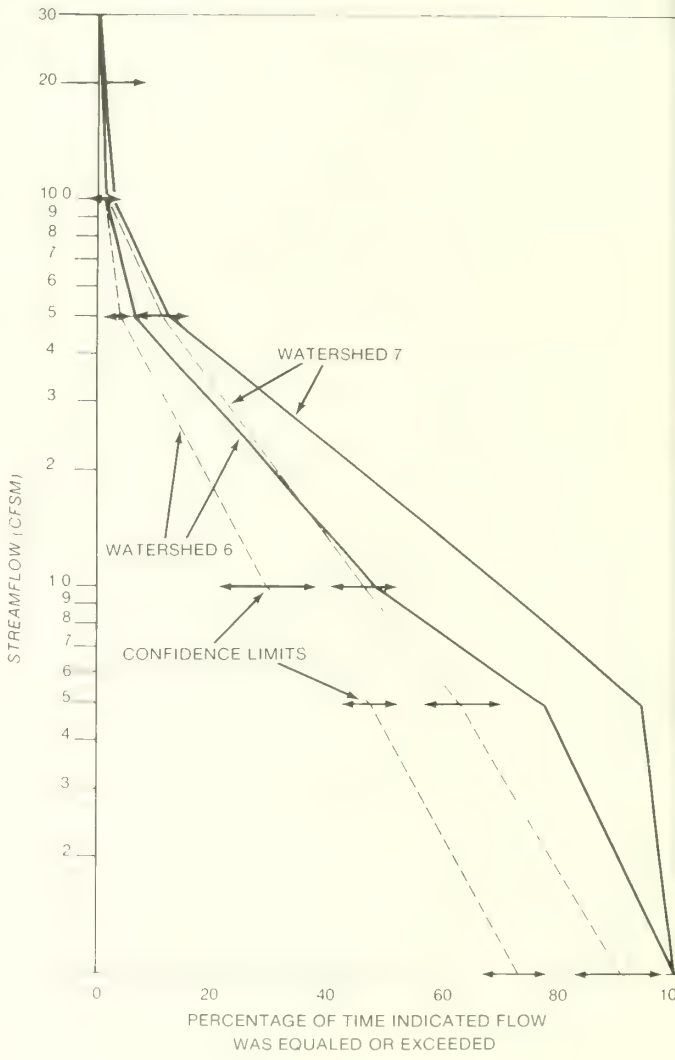



Figure 3.—Effects of deforestation on flow duration, hydrologic year 1969. Solid lines represent measured flow duration; dashed lines are estimated flow duration before deforestation, as derived from regression on measured flow duration from the forested watershed.




mile$^{-2}$ (CFSM) were not significantly affected by deforestation. Flow from the forested watershed was much lower than that from the barren watersheds. In fact, the stream that drained the forested watershed was dry during parts of each summer from 1967 through 1969.

Quickflow is one measure of stormflow. The relationship between quickflow and delayed flow (as defined by *Hibbert and Cunningham 1967*) was probably about the same on all three watersheds when all of them were forested. After two of the watersheds were deforested, water yields from those two increased (table 3), especially during the growing season but somewhat during the dormant season, too. Thus, even though the proportion of dormant season quickflow was unchanged (table 4), absolute amounts of quickflow must have

Table 4.—Flow separation by season and vegetative cover (hydrologic year 1969)

| Flow | Forested watershed (4) | | Barren watershed (6) | |
|---|---|---|---|---|
| | *In.* | *Pct.* | *In.* | *Pct.* |
| *Dormant Season*: | | | | |
| Quick flow | 3.78 | 25 | 3.42 | 25 |
| Delayed flow | 11.34 | 75 | 10.29 | 75 |
| *Growing Season*: | | | | |
| Quick flow | 2.29 | 38 | 2.96 | 28 |
| Delayed flow | 3.78 | 62 | 7.63 | 72 |

increased in proportion to water-yield increases. Wetter soils on the barren watersheds did produce a modestly increased volume of quickflow during the growing season, while delayed flow doubled in volume (table 4). These results, too, demonstrate the role of soil moisture in augmenting low flow without greatly influencing stormflow. This apportionment of quick and delayed flows also substantiates the observation that overland flow is a minor component of runoff from the barren surfaces. In fact, overland flow and soil erosion were uncommon on the barren watersheds, occurring only on and immediately below the steeper roads. Infiltration rates on the barren watersheds in 1969 far exceeded maximum rainfall intensity, varying only insignificantly from those measured on the forested catchment.[2]

Deforestation had no effect on instantaneous peak flows during the dormant season. But during the growing season, instantaneous peak flows were higher on the barren watersheds (table 5), particularly in small storms.

**Table 5.—Instantaneous peak flow comparisons, 1968 growing season, in CFSM**

| Precipitation (inches) | Watershed | | |
|---|---|---|---|
| | 4 | 6 | 7 |
| 0.85 (small storm) | 0.65 | 24.30 | 12.34 |
| 3.64 (largest storm) | 86.53 | 105.75 | 112.93 |
| 26.35 (season total)* | 9.91 | 20.61 | 19.16 |

*Average peak, all storms.

Peak, as used here, includes all measurable streamflow rises during rain or snowmelt. Regression analysis confirmed these findings, indicating a fourfold average increase in peak flow for all growing seasons after the watersheds were deforested.

### Deforestation Effects on the Water Balance

The water-balance equation

$$P - (RO + I + T + L \pm \triangle S) = O \qquad (1)$$

in which

P = Precipitation
RO = Streamflow
I = Canopy and litter interception loss
T = Transpiration
L = Leakage, unmeasured subsurface flow
$\triangle S$ = Gain or loss of soil moisture

is considered a suitably complete statement of rainfall disposition on the forested watershed. This equation neglects the small and relatively constant losses of soil moisture by direct evaporation, photosynthesis, and plant respiration. The water-balance equation provides a means of estimating evaporative losses from rainfall, streamflow, and soil-moisture data. For this purpose, soil-moisture changes to 4 feet were computed, providing data comparable in precision ($\pm$ 5 percent) to that on rainfall and streamflow. The 4-foot soil depth used for moisture measurement is both physically and biologically appropriate; it is about the maximum depth of Calvin soil and contains most of the forest tree roots. Interception losses were estimated from rainfall by the method of Helvey and Patric (*1965*). Transpiration was calculated by solving equation (1) for T, with L always regarded as O. If L was in fact greater than O, this method of calculating T must overestimate transpiration. Calculated evaporative losses (I + T) were then compared to estimated potential evapotranspiration (PET) (table 6).

PET is a useful concept because it specifies an upper limit of evaporative loss that, being controlled by solar energy, is subject to little annual variation. If we accept the 22-inch estimate of Patric and Goswami (*1968*) as a reasonable approximation of mean annual evaporative loss from forest land near Parsons, then the effect of deforestation on evaporation can be deduced. Annual streamflow increases close to 10 inches were maintained during the 3 years watersheds 6 and 7 were barren (table 3). Transpiration and interception losses greatly decreased following deforestation while evaporation from land and stream surfaces must have increased. The net effect, 10 inches more of streamflow, represents that much less evaporation from the barren watersheds. By this means, evaporative loss from

[2]From a report by J. N. Kochenderfer on file at the Parsons Timber and Watershed Laboratory.

Table 6.—Evaporative losses from the forested watershed, estimated by water balance and pan evaporation for the 1969 growing season, in inches

| Soil-moisture measurement dates | Elapsed days | Water balance components | | | | | | Evaporation | |
|---|---|---|---|---|---|---|---|---|---|
| | | P | RO | I | ΔS | T | I+T | Pan[a] | PET |
| 1 May | 0 | — | — | — | — | — | — | — | — |
| 16 May | 15 | 2.44 | 1.23 | 0.38 | +0.01 | 0.82 | 1.20 | 2.62 | 2.04 |
| 22 May | 6 | .12 | .15 | .08 | −0.56 | .45 | .53 | .83 | .65 |
| 5 June | 14 | .40 | .10 | .14 | −1.20 | 1.36 | 1.50 | 2.59 | 2.02 |
| 2 July | 27 | 3.86 | .08 | .79 | −0.27 | 3.26 | 4.05 | 4.56 | 3.56 |
| 16 July | 14 | 3.22 | .08 | .59 | +1.05 | 1.50 | 2.09 | 2.52 | 1.97 |
| 31 July | 15 | 1.72 | .02 | .50 | −0.46 | 1.66 | 2.16 | 2.55 | 1.99 |
| 1 October | 62 | 11.87 | 1.38 | 1.99 | +0.78 | 7.72 | 9.71 | 8.91 | 6.85 |
| Growing season | 153 | 23.63 | 3.04 | 4.47 | −0.65 | 16.77 | 21.24 | 24.58 | 19.08 |

[a]Published class A pan evaporation for the Parsons Climatic Station (U.S. Environmental Data Serv. 1969).

the barren watersheds was estimated at 10 inches less than 22, or 12 inches annually. This cannot, of course, be separated into interception, transpiration, and direct evaporation from soil and water surfaces.

The preceding assumptions provide annual values for all components of the water balance except leakage. Leakage was later calculated as the residue from precipitation (table 7). But here, T for the forested watershed was estimated by subtracting annual interception loss (8 inches) from PET (22 inches).

Precipitation minus streamflow (P — RO), sometimes equated to evapotranspiration, suggests that leakage from the barren watersheds has not changed since the weirs were installed. Before watersheds 6 and 7 were deforested, they averaged 37.28 and 26.89 inches, respectively, in P — RO. After deforestation, the values averaged 24.77 and 13.78 for these watersheds. Thus, both before and after deforestation, P — RO was about 10½ inches greater on watershed 6 than on watershed 7, a finding that may be regarded as further evidence of unvarying leakage.

Table 7.—Annual water balances for the experimental watersheds for hydrologic year 1968, in inches

| Watershed | Water balance components | | | | | | |
|---|---|---|---|---|---|---|---|
| | P | RO | I | T | I+T | ΔS | L |
| Forested (4) | 51 | 20 | 8 | 14 | 22 | 0 | 9 |
| Barren (6) | 49 | 26 | — | — | 12[a] | 0 | 11 |
| Barren (7) | 48 | 35 | — | — | 12[a] | 0 | 1 |

[a]Includes an unknown, probably large, amount of evaporation directly from the barren soil surface.

Table 8.—Effect of leaf development on transpiration, Spring 1969, in inches

| Stage of leaf growth | Date | Mean daily evaporative loss | | |
|---|---|---|---|---|
| | | T | I+T | PET[a] |
| Up to half grown | 5/16 | 0.05 | 0.08 | 0.13 |
| Growth continuing | 5/22 | .08 | .09 | .11 |
| Growth complete | 6/5 | .10 | .11 | .14 |
| Mature | 7/2 | .12 | .15 | .13 |

[a]Potential evapotranspiration estimated from evaporation pan data.

Transpiration estimates derived from water balance (table 6) seem to reflect leaf development. Note that I + T was less than PET before tree leaves were grown, i.e. through June 5. After leaves matured (July 2), calculated evaporative losses (I + T) always exceeded PET, an effect probably caused by assuming leakage to be zero. Mean daily evaporative losses were calculated when T, I + T, and PET (as listed in table 6) were divided by elapsed days. Then the effect of leaf growth on soil-moisture loss became clearer, with daily transpiration losses increasing steadily as leaves grew (table 8). The inflationary effect of leakage on this estimate of transpiration probably persisted, although it was apparent only after the leaves had matured and daily evaporative losses (I + T) averaged 15 percent above PET.

## DISCUSSION

The preceding results have important implications. Foresters know that increased soil moisture on cutover land can improve the survival and growth of new stands. Hydrologists know that added moisture in soil means higher water levels in headwater streams. Even though measurably increased flow is not expected in larger streams, conservationists should know that scattered cutting is generally beneficial to forest water resources. These benefits are not, however, uniform over time and space. Douglass (*1967*) cautions that (1) water saved from evapotranspiration is proportional to the severity of forest cutting, and (2) water savings will not persist after vigorous regrowth has started.

These results also support some older concepts of forest soil moisture and they suggest a promising direction for new study. They show that soils at Parsons always return to near-maximum water content during dormant seasons. Probably the generalization that $\triangle S = 0$ is valid for computing annual water balances in any perhumid climate. This generalization emphatically does not apply to shorter-term water balances during the growing season. The results further suggest that the concept of moisture loss rates remaining undiminished as soils dry (*Veihmeyer and Hendrickson 1955*) is valid in humid climates, as Penman (*1970*) recently concluded. Future studies of the relationship between measured soil-water loss and indexes of evaporative potential could result in more economical methods of study. Soil-moisture measurement is costly, even with neutron probes, and savings will be realized when forest water use can be estimated with confidence from the more easily measured climatic parameters.

The variable-source-area concept (*Hewlett and Hibbert 1967*) is one of the most important recent advances of thinking in forest hydrology. Source areas were not identified in this study because the access tube distribution used was not sufficiently sensitive to spatial variation in soil moisture. Soil-moisture measurement may never help to identify source areas of stormflow, because highly permeable forest soils are subject to large and rapid changes in water content during storms. Between storms, however, soil-moisture content is relatively stable, and more frequent measurements should help to identify the soils with the highest water content that are likely to supply baseflow to streams.

Long ago, deforestation was believed to cause reduced soil moisture and streamflow between storms, and disastrous flooding during storms (*Brooks 1910*). This study revealed almost opposite effects of deforestation, confirming more modern observations (*Douglass 1967*). Why has opinion changed so drastically?

Infiltration data provide clues, if not the full answer to this question. Had the deforested soils been damaged by tillage, heavy grazing, or fire, the infiltration rates would have been reduced dramatically. The soils in this study were not hydrologically damaged by deforestation, and infiltration rates remained near the high rates characteristic of forested land long after the trees were cut. Surface soils did dry quickly and severely after storms, but the dry surface protected the underlying layers from evaporation, and subsurface soil moisture remained at near-maximum levels. Hewlett's (*1961*) concept of soil as the source of headwater streams explains the resultant increase in baseflow.

Another reason that the supposed ill effects of deforestation did not materialize was that this watershed treatment was an experimental and not an economic undertaking. It did not resemble the agricultural practices on which most such ideas are based. No attempt was made to exploit the land after deforestation. Even though the barren soil surface underwent some structural change, it was far less drastic than the complete overturn and compaction that accompanies farming, and thus overland flow, soil erosion, and flooding did not occur. We are continuing to observe the hydrologic behavior of plots of deforested soil because it seems only a matter of time until infiltration will be materially reduced and overland flow and erosion will begin.

With other components of the water balance (precipitation, streamflow, interception, and soil-moisture storage) quantified within stated (.05) limits of precision, the validity of the leakage estimate is contingent on sound

evaluation of the transpiration loss. The method used to evaluate transpiration requires acceptance of the assumption that 0.78 times class A pan evaporation (*Troendle and Phillips 1970*) is a reasonable approximation of potential evapotranspiration from local forests.

The class A pan has been recommended for international use as an index of evaporative demand (*Anonymous 1965*). Often considered a reliable estimator of crop water use (*Christiansen and Hargreaves 1970*), it has been used recently as a check on observed water balance in forests. For example, with plentiful (*Troendle 1970*) and average rainfall (*Waggoner and Turner 1971*), measured moisture loss from forest soil was close to evaporative potential as estimated from class A pan evaporation. These findings tend to confirm reasoning by Patric et al. (*1965*) that in humid regions adequate soil moisture to meet potential demands is available to most forest trees. But after several growing seasons of below-normal rainfall, evaporative loss from another forested watershed averaged only 68 percent of that predicted from the class A pan (*Mustonen and McGuinness 1968*). Wicht (*1967*) considered calculated evapotranspiration a valuable check on observed water balances, but Lee (*1970*) argued that empirical models provide inadequate checks. Nevertheless, numerous observations of high correlations between evaporative losses from pans and those from well-watered vegetation (*Tanner 1967*) suggest that the approach used to quantify the transpiration loss in this study is at least conceptually appropriate.

Evaporative losses from the barren watersheds could not be estimated on the basis of potential evapotranspiration because the required condition that living vegetation completely cover the soil was not met. However, wet-weather evapotranspiration at near-potential rates was expected, even without vegetative cover. Showers often wet the dark land surface, leaving water freely available for evaporation. As for dry weather evaporative loss, soil-moisture data suggest only that it occurred at rates far less than potential. A statement by Milthorpe (*1960*) probably comes as close as possible to describing weather influences on evaporative losses from the barren watersheds: "The total loss of water from soil in a season of intermittent rain and high potential evaporation is therefore independent of the potential evaporative rate and mainly a function of the rainfall, i.e. the frequency of rewetting; on the contrary, in a season of high rainfall and low potential evaporation, it is closely related to the potential evaporation and is independent of rainfall." The net effect, with rain occurring about one day out of three, was evapotranspiration at rates materially less than potential on the barren watersheds.

With all components of the water balance except leakage quantified as accurately as technique permits, how realistic is the unmeasurable residue assigned to leakage? Simple observation establishes that watersheds 4 and 6 do leak. In dry weather, flowing water is visible in stream channels above and below the concrete cutoff walls while no water passes over the weir blades. The "live" channel is about 200 yards long on watershed 6 and at least five times longer on watershed 7, suggesting that far more pervious rock underlies the former. One end of the watershed 6 cutoff wall is known to be seated in loose colluvium; dry-weather measurement shows leakage here at the rate of 2 inches per year. Perhaps the wet-weather leakage is greater.

I attribute other consistent differences in performance of watersheds 6 and 7 to leakage. For example, flow duration (fig. 3) was always greater on watershed 7. Before it was cleared, the stream draining watershed 6 dried up every summer. Watershed 7 dried up only twice during the 7-year calibration period. No-flow conditions persisted more than twice as long on watershed 6. And, if P — RO does in fact approximate evaporative losses, why should anyone expect 10 inches more of water to evaporate consistently from watershed 6? Watersheds 6 and 7 are so similar in all other respects that leakage seems the logical answer.

Although leakage has never been measured directly, its role in streamflow is well known. A case of extreme variation in runoff with small differences in climate occurred in Virginia (*Burford and Lillard 1966*). There, 52 percent of rainfall drained off one watershed

and only 21 percent from another nearby. The authors attribute these differences in runoff to the soil, parent material, and basic geological characteristics of each basin. Inadequacies of the gravimetric soil-moisture-sampling method may have led Rowe and Colman (*1951*) to underestimate evaporative losses when they assigned about half the annual rainfall to leakage. Dagg and Blackie (*1965*) suspected leakage when soil-moisture sampling by electrical resistance revealed cumulative differences between measured and predicted evaporative losses. Although this is by no means a complete survey, these experiences show that leakage, endemic to small watersheds (*Hewlett et al. 1969*), greatly concerns hydrologists and must not be neglected because of the inescapable measurement difficulties.

Better progress is being made toward understanding the components of the water balance and how they relate to each other. Abbe (*1902*) once complained that evaporative loss in nature "is so mixed up with seepage, leakage, and consumption . . . by plants that our metrological data are of comparatively little importance." A more recent commentary on small watershed research (*Slivitzsky and Hendler 1964*) expressed concern about "ignorance of the precise cause and effects of the different components of the hydrologic cycle." Hewlett et al. (*1969*) felt that older studies did merit such criticism, but that it is less justified in modern watershed research where "mechanisms of water loss, storage, and delivery are now studied . . . with all the trappings of modern science." Ward (*1971*) went even further: "if the water balance equation . . . can be solved, then it is likely that the measurements or estimations of the individual components of that balance are satisfactory." This study, at least, was not one of the many attempts to solve the water-balance equation while ignoring leakage "in the quiet hope that it is in fact zero" (*Penman 1963*). Perhaps that fact represents some progress.

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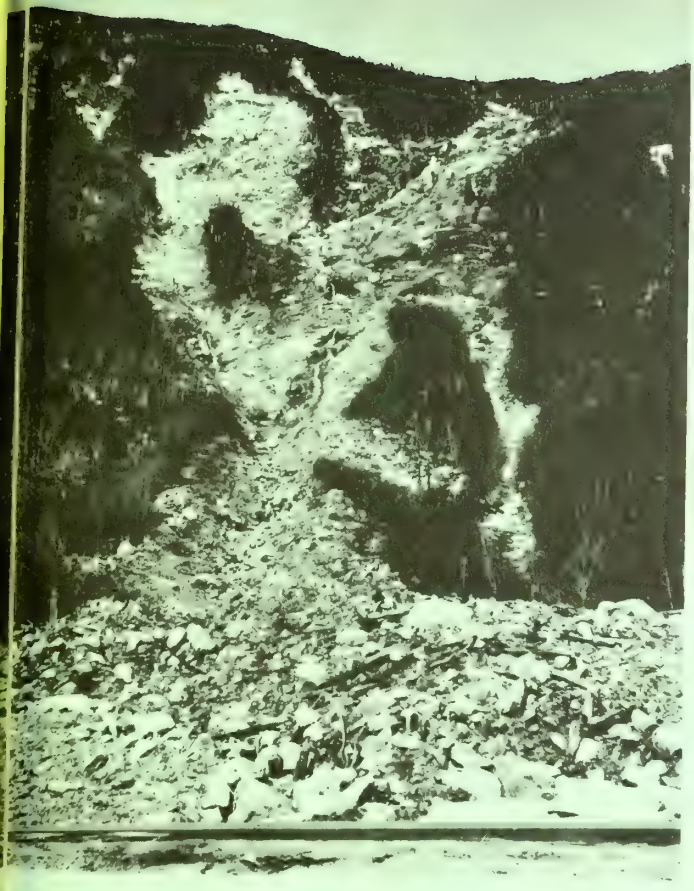

# Nature and Properties of Some Forest Soils in the White Mountains of New Hampshire

by M. C. Hoyle

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WARREN T. DOOLITTLE, DIRECTOR

## The Author

DR. MERRILL C. HOYLE, plant physiologist, has been employed by the Northeastern Forest Experiment Station since 1961. He earned the B.S. and M.S. degrees at the University of Massachusetts, and Ph.D. degree at the University of New Hampshire.

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# Nature and Properties of Some Forest Soils in the White Mountains of New Hampshire


## Abstract

Forested, podzol soils in the White Mountains of New Hampshire have developed in granitic, glacial material. They are coarse textured, acidic, and infertile. As a result of the latter condition, these soils can sustain a forest, but that forest is not healthy and vigorous.


## INTRODUCTION

Not much information is available on the nature and properties of forest soils in the White Mountains. The need for soils information is increasing because the mountains are being used more intensively for outdoor recreation, while the forest continues as an important source of water, wood products, and wildlife. Management of the forest for natural products and an aesthetically pleasing environment will be successful to the degree that we understand the capabilities of the forest soil. Soil, climate, and the acts of men are the main determinants of the forest ecosystem. We cannot alter the climate, but the acts of men can be governed and the soils can be managed. The information given in this paper contributes to our further understanding of some selected forest soils that occur widely throughout the White Mountains.

# METHODS AND MATERIALS

## Soil Descriptions

Soil descriptions (see Appendix) were prepared by soil scientists from the Soil Conservation Service.[1] Nomenclature follows that given in the Soil Survey Manual of the USDA Bureau of Plant Industry, Soils, and Agricultural Engineering (1951).

## Sample Collection and Preparation

All soil samples were collected on the Bartlett Experimental Forest in Bartlett, New Hampshire. (See map in Appendix for exact location.) One-foot squares of the forest floor were cut out and separated into L (litter), F (fermented), and H (humus) layers. The depths of these layers were estimated by taking the mean of numerous measurements around the walls of the square-foot section. Volumes were then calculated for each layer. Six 60-ml. core samples were taken for each mineral horizon.

All samples were air-dried. Then the organic samples were ground, and the mineral samples were each separated by sieving into a greater-than-2 mm. fraction and a less-than-2 mm. fraction. Since all analyses were made on the air-dried, less-than-2 mm. fractions, corrections were applied later to produce values for the coarse material and the oven-dry condition.

## Soil Analyses

Soil moisture content at 0.06 atm. was measured with a mercury manometer in the Buechner funnel method of Wilde and Voigt (1955). Soil pH was determined with a glass electrode in a soil paste. Textural analyses were made with a Bouyoucus hydrometer. And organic matter was estimated by loss on ignition.

Exchangeable sodium, potassium, magnesium, and calcium were extracted with neutral, *N* $NH_4OAc$ and measured by flame photometry. Exchangeable hydrogen and aluminum were extracted with *N* KCl and estimated by titration to pH 4 and pH 8.3, respectively (Coleman, Weed, and McCracken 1955).

[1]The author gratefully acknowledges the assistance of Sidney Pilgrim and Frank Viera (SCS, Durham, N. H.), and Robert Reiske (BLM, Washington, D.C.)

# RESULTS AND DISCUSSION

## Forest Composition

Forests in the area around the soil pits described in this paper are primarily hardwood with a softwood component of from 0 to 20 percent (table 1). The forest around soil No. 15 is mainly softwood. The dominant trees on all plots are between 60 and 100 years old, between 60 and 80 feet tall, and average only about 0.1 inch per year in diameter growth.

Table 1.—*Composition of forests in plots where soils were examined (trees 6 inches d.b.h. and greater)*

| Soil No. | Hardwoods[a] | Softwoods[b] |
|---|---|---|
| | *Percent* | *Percent* |
| 1 | 91 | 9 |
| 3 | 97 | 3 |
| 4 | 80 | 20 |
| 11 | 85 | 15 |
| 15 | 31 | 69 |
| 17 | 100 | 0 |

[a]Primary species: beech, red maple, sugar maple, yellow birch, paper birch, white ash.
[b]Primary species: red spruce, balsam fir, hemlock.

## Forest Floor

The forest floor on all soils is typically mor, with its three layers of L (litter), F (fermented), and H (humus). Under the predominantly hardwood forests the H layer is thin (½ to 3 inches), but under the predominantly softwood forest the H layer is 13

inches thick. This large difference in the depth of the H layer is a result of the difference between the microclimate under hardwoods and that under softwoods. The forest floor is warmer and drier under hardwood forest than under softwoods, conditions that generally favor breakdown of organic detritus over accumulation. As a consequence, the *available* nitrogen, for tree growth, is generally higher in the forest floor of hardwood stands.

## Mineral Soil

All soils developed in glacial till or glacial outwash laid down during the Wisconsin age. Rocks are abundant, both in the soil and scattered over the surface. The rocks are granitic and contain orthoclase feldspar, quartz, muscovite mica, biotite mica, and small amounts of other minerals. Chemically, these minerals contain potassium aluminosilicate, silica, potassium aluminosilicate with hydroxyl group, and potassium (ferromagnesium) aluminosilicate with hydroxyl group, respectively. These minerals weather slowly and have produced coarse-textured sandy soils of low fertility. The clays are probably kaolinitic. There is little development of structure in the soils. Most soils are classified as weak, fine granular. In the Becket soil (no. 17) and the poorly drained soil (no. 11), pans are present. This massive structure causes lateral flow of water through the soil.

In the well-drained soils, there is a strong profile development (fig. 1) that is typical of podzols. However, some of the soils have been repeatedly disturbed by windthrow (e.g., soil no. 1) so horizons have been mixed and/or

Figure 1.—A well-developed podzol profile showing the characteristic gray, leached horizon (A2) above the reddish-brown horizon (B2) of Fe and Al accumulation. The upper black layer is composed of decayed organic matter.

buried. As a result, the colors are not of their usual intensity and the horizons show an unusual sequence. In general, though, the distinct ashy gray A2 and the reddish-orange B2 horizons are quite distinct. In many soils, iron has accumulated in the B2 to a considerable degree and some ortstein (iron pan) is present.

In poorly drained soils, olive gray to mottled gray colors of the gley layers are found. These horizons develop as a result of reducing conditions when water drainage is impeded and oxygen content is very low.

## Physical Properties (Tables 2 and 3)

Bulk density varies greatly, from a low of 0.1 g/cc. in humus to a high of nearly 1.7 g/cc. in the C horizons. The general trend is

Table 2.—*Physical properties of soils*

| Horizon | Bulk density | Textural analyses | | | Sand separates | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | S | Si | C | VCS | CS | MS | FS | VFS |
| | g./cc. | | | | *Percent* | | | | |
| *Soil No. 1* | | | | | | | | | |
| *Berkshire* | | | | | | | | | |
| H | 0.27 | — | — | — | — | — | — | — | — |
| A2 | 1.16 | 50.9 | 27.2 | 2.3 | 13.5 | 16.7 | 11.1 | 32.3 | 26.5 |
| B21h | .78 | 63.8 | 23.8 | .4 | 7.9 | 18.5 | 15.4 | 34.2 | 24.1 |
| B21ir | .87 | 54.8 | 23.8 | .3 | 12.0 | 17.8 | 13.1 | 33.7 | 23.3 |
| B22 | 1.32 | 62.9 | 30.0 | .8 | 14.4 | 14.4 | 10.9 | 33.5 | 26.8 |
| A2b | 1.34 | 46.6 | 34.9 | 1.0 | 11.9 | 11.3 | 9.4 | 34.6 | 32.8 |
| B21b, B22b | 1.31 | 53.6 | 18.7 | 3.4 | 14.9 | 14.8 | 12.5 | 33.2 | 24.6 |
| B3b | 1.46 | 57.6 | 16.9 | 1.8 | 1.9 | 19.4 | 11.8 | 29.2 | 20.5 |
| C1, C2 | 1.49 | 56.7 | 28.6 | 1.8 | 9.2 | 9.5 | 9.2 | 35.1 | 37.0 |
| *Soil No. 3* | | | | | | | | | |
| *Acton* | | | | | | | | | |
| H | .30 | — | — | — | — | — | — | — | — |
| A2 | 1.32 | 45.7 | 40.0 | 2.5 | 8.8 | 9.7 | 7.8 | 31.8 | 41.9 |
| B21h, B22ir | .98 | 62.7 | 20.5 | .7 | 13.9 | 13.9 | 17.1 | 32.1 | 23.0 |
| B23, B24 | 1.32 | 54.2 | 20.7 | 0 | 18.9 | 17.9 | 13.2 | 27.6 | 20.2 |
| B3, C | 1.50 | 53.8 | 20.9 | .9 | 13.3 | 14.5 | 13.3 | 35.3 | 24.1 |
| *Soil No. 4* | | | | | | | | | |
| *Berkshire* | | | | | | | | | |
| H | .27 | — | — | — | — | — | — | — | — |
| A2 | 1.20 | 52.0 | 40.3 | 2.3 | 5.9 | 11.3 | 11.7 | 37.3 | 33.7 |
| B21h | .97 | 64.8 | 16.0 | .6 | 15.5 | 24.8 | 15.4 | 27.9 | 16.4 |
| B22ir | 1.11 | 60.2 | 17.9 | 0 | 15.4 | 18.0 | 14.9 | 31.5 | 20.2 |
| B23, B24 | 1.37 | 56.4 | 19.2 | 0 | 13.3 | 14.5 | 13.3 | 35.3 | 24.1 |
| B3 | 1.34 | 60.1 | 27.4 | .4 | 9.8 | 13.7 | 11.2 | 36.2 | 29.0 |
| C1 | 1.66 | 55.4 | 31.4 | 0 | 10.1 | 12.6 | 10.8 | 36.0 | 30.5 |
| *Soil No. 11* | | | | | | | | | |
| *Undetermined series* | | | | | | | | | |
| H | .08 | — | — | — | — | — | — | — | — |
| A1 | .43 | 77.8 | 14.2 | 2.7 | 21.0 | 22.5 | 11.6 | 41.0 | 3.8 |
| A2g | 1.61 | 62.6 | 21.3 | 4.2 | 12.5 | 17.6 | 17.6 | 34.0 | 18.4 |
| Cg1 | 1.65 | 62.6 | 17.4 | 3.4 | 17.1 | 18.8 | 15.8 | 32.8 | 15.5 |
| *Soil No. 15* | | | | | | | | | |
| *Croghan* | | | | | | | | | |
| H | .06 | — | — | — | — | — | — | — | — |
| A2 | 1.11 | 78.5 | 20.8 | 0 | 3.3 | 10.9 | 20.1 | 54.7 | 14.3 |
| B21h | .93 | 85.4 | 10.4 | .8 | 4.3 | 15.0 | 21.5 | 43.4 | 8.9 |
| B22ir | 1.21 | 88.4 | 4.3 | 1.6 | 14.7 | 31.9 | 35.3 | 27.0 | 1.4 |
| B23ir | 1.37 | 89.0 | 2.0 | 2.7 | 3.8 | 12.6 | 29.0 | 51.2 | 4.9 |
| B24 | 1.43 | 90.2 | 1.9 | 4.3 | 14.6 | 30.5 | 23.0 | 27.5 | 5.2 |
| B3 | 1.34 | 74.8 | 24.9 | 0 | 1.6 | 6.3 | 14.3 | 45.0 | 27.8 |
| C1, C2 | 1.31 | 74.2 | 17.7 | .8 | 16.1 | 23.4 | 18.1 | 29.5 | 12.8 |
| *Soil No. 17* | | | | | | | | | |
| *Becket* | | | | | | | | | |
| H | .24 | — | — | — | — | — | — | — | — |
| B2ir | .95 | 54.0 | 26.0 | 0 | 15.0 | 18.4 | 14.7 | 31.4 | 20.4 |
| B&A | 1.36 | 46.5 | 13.6 | 1.0 | 19.4 | 18.0 | 14.1 | 29.8 | 18.7 |
| C1x, C2 | 1.43 | 57.5 | 22.6 | .3 | 16.1 | 17.3 | 12.0 | 32.0 | 22.7 |

Table 3.—*Volumes of air and water in various horizons of representative podzol soils on the Bartlett Experimental Forest*

| Horizon | Pore volume | Water volume | Air volume |
|---|---|---|---|
| | *Percent* | *Percent* | *Percent* |
| *Soil No. 21 Hermon (well drained)* | | | |
| H | 95.9 | 45.2 | 50.7 |
| A2 | 63.4 | 46.0 | 17.4 |
| B22h | 72.8 | 43.3 | 29.5 |
| B23 | 63.7 | 38.3 | 25.6 |
| B3 | 54.7 | 28.3 | 26.4 |
| C | 46.1 | 25.0 | 21.1 |
| *Soil No. 22 Hermon (well drained)* | | | |
| H | 89.6 | 18.2 | 71.9 |
| H-A2 | 65.3 | 32.1 | 33.2 |
| B22 | 64.5 | 35.0 | 29.5 |
| B23 | 51.0 | 27.9 | 23.1 |
| B3 | 52.8 | 27.3 | 25.5 |
| B3C | 47.8 | 12.0 | 35.8 |
| *Soil No. 23 Waumbek (moderately well drained)* | | | |
| H | 83.4 | 36.9 | 46.5 |
| A2 | 51.3 | 32.4 | 18.9 |
| B2h | 62.4 | 28.9 | 33.5 |
| B22 | 51.0 | 32.4 | 18.6 |
| B23 | 42.3 | 9.2 | 33.1 |
| B3g | 46.1 | 25.6 | 20.5 |
| *Soil No. 24 Whitman (poorly drained)* | | | |
| H | 91.7 | 23.8 | 67.9 |
| A | 66.8 | 36.6 | 30.2 |
| G | (massive, could not take core sample) | | |

for bulk density to increase with greater depth, but this trend is altered in B2 horizons where organic matter accumulates (table 5).

The soil horizons are all coarse-textured, and may contain as much as 90 percent sand, but sand content usually ranges between 50 and 70 percent. Fifty to sixty percent of the sand is composed of fine and very fine fractions, and the remaining 40 to 50 percent is about equally divided among the very coarse, coarse, and medium sand fractions. Clay content is very low, and varies from 0 to only 4.3 percent.

As a consequence of this coarse texture, the glacial soils are quite porous (table 3), except where iron pan develops in B2 horizons or silt pans form in the lower B or C horizons (e.g., in a Becket soil). Total porosity varies from 40 to 70 percent in the mineral horizons and is estimated at 80 to 90 percent in humus layers of the forest floor. At field capacity (water retained against a tension of 0.06 atm.), the pores are occupied by water and air about equally, but in some horizons there is a considerable departure from this generalization. Very often the A2 horizons will show some resemblance to a platy structure and the air volume at field capacity may be down to 17 percent (e.g., soil nos. 21 and 23, table 3). An air volume of 15 percent is thought to be the limit for good root development. However, since the pore volume occupied by water is constantly changing, the air volume must change also.

In terms of water-holding capacity, these water volume percentages translate into 10 to 15 inches of total water for a 30-inch depth of typical glacial soil in the White Mountains. The high porosity of these soils also indicates that percolation rates are high. In areas where these highly porous soils are underlain by hardpan, landslides are quite common (fig. 2).

Figure 2.—A recent landslide in Franconia Notch. Deciduous trees colonize these new slide areas and conifers follow much later. The sites of older landslides are marked by deciduous trees in the photograph.

## Chemical Properties (Tables 4 and 5)

All of the soils are very acidic (table 4). Surface horizons vary from pH 3 to 4 and subsoil horizons vary between pH 4 and 5.5. Humus horizons are extremely acid and may go below pH 3 (e.g., soil no. 15, table 4).

Contrary to general belief, it is the large quantity of exchangeable aluminum (Al), and not hydrogen (H), that is the primary cause of high acidity throughout the profile of these soils (tables 5 and 6). Exchangeable H is found only in the humus and A2 layers of soils with good drainage, and is not detected in poorly drained soils (tables 5 and 6). Consequently, H contributes only in part to acidity in the surface soil and not at all to acidity in the subsoil.

The quantity of exchangeable cations (i.e., $NA^{+}$, $K^{+}$, $Mg^{++}$, $Ca^{++}$, $Al^{+++}$) in these podzol soils is a reflection of the mineralogy of the parent rock, the low base exchange capacity, the severity of leaching by rainwater, and the annual deposition of leaves on the forest floor.

Potassium and Al are weathered from orthoclase feldspar (the predominant constituent of granite); Na, Ca, and Mg come from the white and black micas, and small amounts of other dark minerals. The total quantity of these nutrient-supplying minerals is small. The base exchange capacity (i.e., the sum of all exchangeable cations that can be adsorbed) of the mineral soil is also small because clay content is low. In addition, these mountain soils receive about 4 inches per month of rainfall so the cations in soluble phase are leached rather severely from the well-drained soils (e.g., nos. 1, 3, 15, and 21). Leaching of cations is somewhat retarded in soils with hardpan (no. 17) or soils with gley layers (soil nos. 11 and 24), so their quantities of exchangeable cations are higher.

The annual leaf fall in autumn counteracts this leaching effect, and the decomposition of leaves produces a higher cation content in the surface horizons than in the subsurface horizons. This phenomenon is known as nutrient cycling.

Calcium content is higher than that of the other elements in decomposing leaves because of the peculiarities of tree metabolism. Calcium not only accumulates in the foliage in greater quantities than Na, K, or Mg, but Ca is *not* translocated out of the foliage just before leaf fall as are large portions of the other elements. Aluminum, on the contrary, accumulates in tree roots and very little is carried into the leaves. Consequently, there is much less enrichment of Al in the soil surface than there would be if the metabolism of Al were the same as that of Ca.

In general, exchangeable Al in the soil is highest in the upper B horizons (soil no. 15, table 5, is a good example) where it accumulates, along with Fe, as a consequence of the normal podzolization process of soil weathering.

Before we leave the discussion of exchangeable cations, let me explain why two different units are used to express these quantities.

Historically, milliequivalents (meq.) per 100 grams of soil have been widely used in soil science to quantify exchangeable cations. These units have proved quite satisfactory in reference to the plow layer of agricultural soils because cultivation tends to produce a uniform bulk density across a wide range of soil types. Hence when milliequivalents for a plow layer are expressed on an equal weight basis (i.e., per 100 g.) it is usually true that the volumes of soil are equal also. But in forest soils there is no single homogeneous layer that can be examined to evaluate soil fertility. Tree roots develop in a number of horizons that differ widely in bulk density. There is a considerable difference in volume between 100 g. of humus and 100 g. of A2 horizon soil (table 2).

Therefore meq./100 g. soil *does not* provide a legitimate basis for comparing exchangeable cations[2] between horizons or between soils. By using bulk density, one can convert meq./100 g. of soil to meq/liter of soil and obtain an equal basis for comparison that is pertinent to a forest soil in its native state. For example, in table 4 it appears that there is

[2]Exchangeable cations make up a major fraction of each nutrient element in soil that is available to a plant, and their concentration often correlates well with tree growth.

Table 4.—*Soil Chemical properties (weight basis)*

| Horizon | O.M. | Exchangeable cations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Na | K | Ca | Mg | Al | H | pH |
| | *Percent* | | | *meq./100 g. soil* | | | | |
| *Soil No. 1* | | | | | | | | |
| *Berkshire* | | | | | | | | |
| H | 62.0 | 0.60 | 1.35 | 7.26 | 0.70 | 4.33 | 2.98 | 3.2 |
| A2 | 2.3 | .03 | .08 | .29 | 0 | 2.22 | .24 | 3.8 |
| B21h | 15.7 | .03 | .12 | .06 | .05 | 5.46 | .20 | 4.2 |
| B21ir | 9.7 | .06 | .06 | .10 | .03 | — | — | 4.7 |
| B22 | 3.2 | .03 | .02 | .09 | 0 | — | — | 4.9 |
| A2b | 1.9 | .03 | .02 | .09 | 0 | — | — | 4.8 |
| B21b, B22b | 2.6 | .03 | .01 | .08 | 0 | — | — | 4.8 |
| B3b | 1.5 | .02 | .02 | .05 | 0 | — | — | 5.1 |
| C1, C2 | .8 | .02 | .01 | .03 | 0 | — | — | 5.0 |
| *Soil No. 3* | | | | | | | | |
| *Acton* | | | | | | | | |
| H | 48.6 | .40 | .95 | 7.21 | 1.02 | 3.31 | 1.63 | 3.4 |
| A2 | .6 | .03 | .04 | .18 | 0 | 1.19 | .11 | 4.0 |
| B21h, B22ir | 1.5 | .03 | .04 | .36 | 0 | — | — | 5.0 |
| B23, B24 | 1.3 | .03 | .02 | .03 | 0 | .44 | 0 | 5.1 |
| B3, C | .4 | .01 | .01 | .03 | 0 | .17 | 0 | 5.2 |
| *Soil No. 4* | | | | | | | | |
| *Berkshire* | | | | | | | | |
| H | 46.8 | .49 | 1.22 | 2.13 | .31 | 6.17 | 4.52 | 3.1 |
| A2 | 2.4 | .03 | .06 | .12 | .05 | 1.68 | .55 | 3.4 |
| B21h | 19.6 | .03 | .07 | .02 | 0 | — | — | 3.9 |
| B22ir | 9.2 | .03 | .02 | .04 | 0 | .96 | 0 | 4.8 |
| B23, B24 | 2.3 | .02 | .01 | .06 | 0 | .41 | 0 | 4.9 |
| B3 | 2.5 | .03 | .01 | .04 | 0 | .41 | 0 | 4.8 |
| C1 | 1.3 | .03 | 0 | .03 | 0 | .37 | 0 | 4.9 |
| *Soil No. 11* | | | | | | | | |
| *Undetermined series* | | | | | | | | |
| H | 25.6 | .58 | 1.26 | 9.91 | 1.36 | 2.16 | 0 | 4.5 |
| A1 | 21.4 | .02 | .34 | 4.61 | .50 | 1.12 | 0 | 5.0 |
| A2g | 1.2 | .03 | .04 | .35 | 0 | .78 | 0 | 5.2 |
| Cg1 | .8 | .03 | .05 | .26 | 0 | .50 | 0 | 5.1 |
| *Soil No. 15* | | | | | | | | |
| *Croghan* | | | | | | | | |
| H | 96.0 | .70 | 2.43 | 6.86 | 4.15 | 6.30 | 11.17 | 2.4 |
| A2 | 1.6 | .03 | .44 | .17 | 0 | 1.86 | .37 | 3.6 |
| B21h | 10.7 | .03 | .08 | .10 | 0 | 7.16 | .97 | 3.8 |
| B22ir | 10.3 | .03 | .02 | .09 | 0 | 2.69 | 0 | 4.3 |
| B23ir | 4.4 | .02 | .01 | .10 | 0 | .50 | 0 | 4.6 |
| B24 | .9 | .02 | .01 | .11 | 0 | .16 | 0 | 4.5 |
| B3 | 1.0 | .03 | .01 | .10 | 0 | .15 | 0 | 5.0 |
| C1, C2 | .5 | .02 | .01 | .09 | 0 | .22 | 0 | 4.8 |
| *Soil No. 17* | | | | | | | | |
| *Becket* | | | | | | | | |
| H | 21.0 | .47 | .77 | 4.36 | .56 | 1.38 | 0 | 3.9 |
| B2ir | 6.0 | .02 | .07 | .23 | .05 | 1.88 | 0 | 4.4 |
| B&A | 1.5 | .09 | .04 | .29 | 0 | .44 | 0 | 5.1 |
| C1x, C2 | .7 | .11 | .04 | .21 | — | .38 | 0 | 5.5 |

(—) Not analyzed.

Table 5.—*Soil chemical properties (volume basis)*

| Horizon | O.M. | Exchangeable cations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Na | K | Ca | Mg | Al | H |
| | *g./liter* | *meq./liter soil* | | | | | |
| *Soil No. 1* | | | | | | | |
| *Berkshire* | | | | | | | |
| H | 167.3 | 1.62 | 3.66 | 19.59 | 1.89 | 11.69 | 8.05 |
| A2 | 27.2 | .35 | .94 | 3.38 | 0 | 25.82 | 2.73 |
| B21h | 122.9 | .26 | .93 | .43 | .36 | 42.59 | 1.56 |
| B21ir | 84.5 | .49 | .53 | .90 | .29 | — | — |
| B22 | 42.4 | .43 | .24 | 1.18 | 0 | — | — |
| A2b | 25.9 | .39 | .21 | 1.17 | 0 | — | — |
| B21b, B22b | 34.0 | .34 | .09 | 1.01 | 0 | — | — |
| B3b | 22.0 | .30 | .22 | .67 | 0 | — | — |
| C1, C2 | 11.5 | .36 | .12 | .45 | 0 | — | — |
| *Soil No. 3* | | | | | | | |
| *Acton* | | | | | | | |
| H | 146.4 | 1.20 | 2.87 | 21.70 | 3.06 | 9.96 | 4.90 |
| A2 | 8.4 | .38 | .58 | 2.39 | 0 | 15.75 | 1.40 |
| B21h, B22ir | 14.8 | .31 | .34 | 3.48 | 0 | — | — |
| B23, B24 | 16.9 | .36 | .20 | .40 | 0 | 5.81 | 0 |
| B3, C | 5.6 | .18 | .10 | .39 | 0 | 2.49 | 0 |
| *Soil No. 4* | | | | | | | |
| *Berkshire* | | | | | | | |
| H | 125.6 | 1.31 | 3.28 | 5.70 | .83 | 16.53 | 12.11 |
| A2 | 29.5 | .38 | .67 | 1.47 | .57 | 20.16 | 6.60 |
| B21h | 190.0 | .30 | .71 | .19 | 0 | — | — |
| B22ir | 101.8 | .30 | .28 | .41 | 0 | 10.69 | 0 |
| B23, B24 | 31.0 | .32 | .10 | .85 | 0 | 5.62 | 0 |
| B3 | 33.5 | .36 | .12 | .47 | 0 | 5.48 | 0 |
| C1 | 22.2 | .45 | 0 | .43 | 0 | 6.08 | 0 |
| *Soil No. 11* | | | | | | | |
| *Undetermined series* | | | | | | | |
| H | 20.5 | .47 | 1.01 | 7.92 | 1.09 | 1.73 | 0 |
| A1 | 92.5 | .07 | 1.45 | 19.96 | 2.18 | 4.86 | 0 |
| A2g | 18.8 | .47 | .71 | 5.69 | 0 | 12.52 | 0 |
| Cgl | 12.8 | .41 | .83 | 4.21 | 0 | 8.30 | 0 |
| *Soil No. 15* | | | | | | | |
| *Croghan* | | | | | | | |
| H | 64.3 | .46 | 1.58 | 4.46 | 2.69 | 4.10 | 7.26 |
| A2 | 18.1 | .32 | 4.87 | 1.88 | 0 | 20.57 | 4.09 |
| B21h | 99.6 | .30 | .77 | .96 | 0 | 66.85 | 9.00 |
| B22ir | 124.1 | .40 | .23 | 1.05 | 0 | 32.51 | 0 |
| B23ir | 60.6 | .30 | .10 | 1.32 | 0 | 6.79 | 0 |
| B24 | 12.1 | .31 | .13 | 1.53 | 0 | 2.23 | 0 |
| B3 | 13.2 | .36 | .13 | 1.34 | 0 | 2.00 | 0 |
| C1, C2 | 7.8 | .31 | .13 | 1.20 | 0 | 2.82 | 0 |
| *Soil No. 17* | | | | | | | |
| *Becket* | | | | | | | |
| H | 51.0 | 1.15 | 1.87 | 10.59 | 1.35 | 3.36 | 0 |
| B2ir | 57.2 | .23 | .69 | 2.16 | .45 | 17.88 | 0 |
| B&A | 20.3 | 1.26 | .50 | 3.94 | — | 6.04 | 0 |
| C1x, C2 | 101.9 | 1.52 | .57 | 3.03 | — | 5.37 | 0 |

(—) Not analyzed.

more exchangeable A1 in humus (H) than in A2, but in table 5 it is quite clear that the reverse is true. The weight-based figures are misleading because of the large difference in bulk density between these horizons.

Clearly, the expression of milliequivalents on a volume basis has more meaning and therefore greater utility than the expression of milliequivalents on a weight basis. It is hoped that the volume unit will be more widely adopted.

Other important plant nutrients such as N, P, and Mn have not been measured directly in these forest soils, but we do have some knowledge about their availability to trees from the foliar analysis of seedlings growing in the different horizons. In general, humus supplies adequate amounts of N and P, but too much Mn. In contrast, mineral soil horizons[3] are severely deficient in P and N; while Mn was so plentiful as to be toxic in the A2 horizon but merely adequate in the subsoil horizons.

The concentration of each of these three elements is influenced by different factors, so a direct examination of their availability in soils is difficult. This is an area in forest soils research where much more work is needed.

The organic matter in soils play many roles. Organic matter reduces bulk density, improves water-holding capacity, and serves as a reserve store of plant nutrients. Humus is, of course, high in organic matter on a weight basis (table 4)—generally higher than any mineral horizon. However, on a volume basis organic matter may occasionally be higher in some mineral horizons (especially B2h horisons) than in the humus (table 5). This is the result of differences in bulk density.

When the forest cover is reduced by fire, by insects, or by harvesting, the microclimate of the forest floor changes. Generally there is an increase in temperature and a decrease in moisture. As a result of this more favorable environment, microbe activity increases and organic matter is broken down much more rapidly than under a closed canopy. Mineral nutrients are released, and organic N is converted to inorganic N in the forms of ammonium and nitrate, which are then available to plants.

Pioneer plants such as paper birch, pin cherry, and *Rubus* sp., which have a high N requirement, can then become established in the disturbed area as a result of the increased N supply. Shortly thereafter, other woody species like yellow birch, red and sugar maple, and white ash become established beneath the pioneer species and the northern hardwood forest has effectively succeeded itself. *The main ecological key to this succession-in-kind is the release of N stored in the forest floor.*

[3]These determinations have been made only with soil no. 21 (table 6), but the chemical analyses of the various soils are so similar that the results should apply quite well to all.

# SUMMARY COMMENTS

The primary parent rock of the forest soils in the White Mountain National Forest in New Hampshire is granite. The profiles have developed in either glacial till or glacial outwash, and are coarse textured, highly acidic, and infertile. All profiles are typically podzol except where gleization has occurred in poorly drained soils. The forest cover is birch-beech-maple, spruce-fir, or an admixture.

The forest floor is composed of litter, fermented, and humus layers. The humus is classified as mor. Under proper conditions of

Table 6. — *Chemical analyses of two additional podzol profiles*

| Horizon | Exchangeable cations | | | | |
|---|---|---|---|---|---|
| | K | Mg | Ca | Al | H |
| | *meq./liter soil* | | | | |
| *Soil No. 21 Hermon (well drained)* | | | | | |
| H | 2.87 | 5.75 | 23.27 | 11.47 | 2.99 |
| A2 | 1.00 | 0 | 5.63 | 13.09 | 4.75 |
| B22 | .52 | .72 | 0 | 15.12 | 0 |
| B23 | .28 | 1.25 | 0 | 4.22 | 0 |
| B3 | .61 | 0 | 0 | 5.52 | 0 |
| C | .84 | 0 | 0 | 4.72 | 0 |
| *Soil No. 24 Whitman (poorly drained)* | | | | | |
| H | 2.49 | 3.78 | 25.53 | 3.55 | 0 |
| A | 1.50 | 2.89 | 19.62 | 4.03 | 0 |
| G | 2.68 | .70 | 4.71 | 2.27 | 0 |

moisture and temperature, large stores of N are released (by mineralization) from the humus. As a result of nutrient cycling, humus is also enriched (relative to the mineral horizons) in cations, especially Ca. *Consequently, humus is the main source of nutrients for the forest vegetation.*

Horizons of the mineral soil have good physical properties of bulk density (except where hardpan or iron pan has developed), moisture-holding capacity, and porosity or aeration. But the levels of plant nutrients are very low in most cases. Available P is critically low (for tree growth) because total P is low and much of it is tied up with Fe and Al under the existing acidic conditions. *The available cations necessary for plant growth* (K, Mg, and Ca) *are critically low in subsoil horizons, especially Ca and Mg.* Not only is the parent rock low in total content of these two elements, but there is little cation-exchange capacity (little or no clay) to retain these cations against severe leaching from a high monthly rainfall.

As a consequence of low Ca and high Al, *there is very little root development below the A horizon.* This is especially true for hardwood species, and blowdowns are common, as the mound and depression topography shows.

I have shown how these soils are able to sustain the forest vegetation, *but it should be understood that being sustained is a long way from being healthy.* The "cure" (as indicated by research) is forest fertilization. Fortunately these sandy forest soils are quite responsive (relative to growth and vigor of the forest vegetation) to the addition of nutrient elements. Maybe someday the wastes of our cities will be used to supply these nutrients, and we will have both healthier cities and healthier forests!

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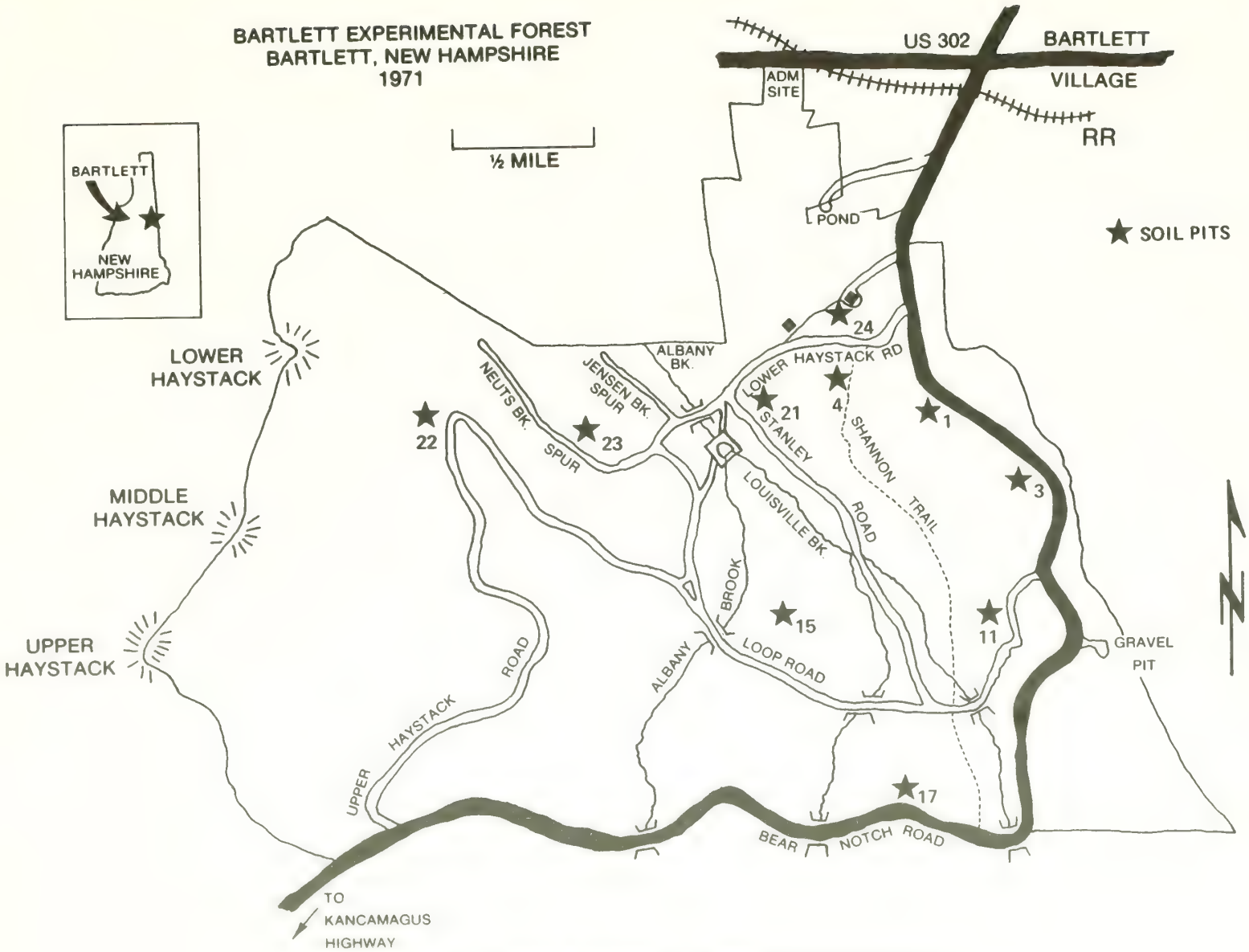


Map of Bartlett Experimental Forest showing location of soil pits.

## SOIL NUMBER 1

1. *Miscellaneous Plot Data*
   - a. Location — Bartlett Experimental Forest, Compartment 14
   - b. Slope — 15 percent
   - c. Aspect — N 80°E
   - d. Elevation — 940 feet
   - e. Landform — Gently rolling to steep and hilly uplands of the White Mountains
   - f. Parent material — Moderately coarse textured glacial till of late Wisconsin age

2. *Soil Classification*
   - a. Placement in New Soil Classification System:
     - (1) Subgroup — Typic Haplorthods
     - (2) Family — Coarse loamy, mixed, frigid
     - (3) Series — Berkshire
   - b. Placement in 1938 Soil Classification System: Podzol
   - c. Drainage class — Well drained

3. *Soil Description*

Berkshire very stony fine sandy loam—buried solum variant (all colors for moist soil)

| *Horizon* | *Depth (inches)* | *Description* |
|---|---|---|
| 01 | 1.5-1.0 | Loose leaf litter |
| 02 | 1.0-0 | Black (N 2/) humus |
| A2 | 0-1 | Gray (10YR 6/1) fine sandy loam; structure weak, fine granular* |
| B21h | 1-2 | Dark reddish brown (5YR 2/2) loamy fine sand |
| B21ir | 2-4 | Yellowish red (5YR 4/6) fine sandy loam |
| B22 | 4-16 | Yellowish brown (10YR 5/6) loamy fine sand |
| A2h | 16-18 | Gray (10YR 6/1) fine sandy loam |
| B21b | 18-22 | Strong brown (7.5YR 5/6) fine sandy loam |
| B22b | 22-27 | Dark yellowish brown (10YR 4/4) fine sandy loam |
| B3b | 27-34 | Matrix light olive brown (2.5Y 5/4) loamy fine sand, with few fine distinct strong brown (7.5YR 5/8) mottles, massive |
| C1 | 34-41 | Matrix light brownish gray (2.5Y 6/2) fine sandy loam, massive |
| C2 | 41-46 | Matrix light brownish gray (2.5Y 6/2) fine sandy loam, with many medium distinct yellowish red (5YR 5/8) mottles, massive |

4. *Remarks*
   - a. The profile described is on a tree throw mound. The morphology and horizon sequence of this pedon may be representative of other Berkshire pedons that have had windthrow activity
   - b. Weighted average texture of the 10- to 40-inch control section is coarse loamy textural family
   - c. Profile description by Pilgrim, Viera and Reiske

*Unless noted otherwise, all other horizons in these descriptions are weak, fine granular in structure.

## SOIL NUMBER 3

1. *Miscellaneous Plot Data*
   - a. Location — Bartlett Experimental Forest, Compartment 15
   - b. Slope — 10 percent
   - c. Aspect — N 30° E
   - d. Elevation — 1,000 feet
   - e. Landform — Gently rolling to steep and hilly uplands of the White Mountains
   - f. Parent material — Moderately coarse textured glacial till of late Wisconsin age

2. *Soil Classification*
   - a. Placement in New Soil Classification System:
     - (1) Subgroup — Aquic Entic Haplorthods[4a]
     - (2) Family — Sandy, siliceous, mesic[4b]
     - (3) Series — Acton
   - b. Placement in 1938 Soil Classification System: Brown Podzolic
   - c. Drainage class — Moderately well drained

3. *Soil Description*

Acton very stony fine sandy loam (all colors for moist soil)

| *Horizon* | *Depth (inches)* | *Description* |
|---|---|---|
| 01 | 1.5-1.0 | Loose leaf litter |
| 02 | 1.0-0 | Black (10YR 2/1) humus |
| A2 | 0-2 | Gray (10YR 6/1) fine sandy loam |
| B21h | 2-3 | Black (5YR 2/1) fine sandy loam |
| B22ir | 3-6 | Yellowish red (5YR 4/6) loamy fine sand |
| B23 | 6-17 | Yellowish brown (10YR 4/4) loamy fine sand |
| B24 | 17-25 | Matrix light olive brown (2.5Y 5/4) gravelly loamy fine sand, few fine distinct strong brown (7.5YR 5/6) mottles in lower part of horizon, weak medium subangular, blocky |
| B3 | 25-28 | Matric light olive brown (2.5Y 5/4) gravelly loamy fine sand with many fine and medium distinct strong brown (7.5YR 5/6) mottles, massive |
| C | 24-44 | Matrix light brownish gray (2.5Y 6/2) gravelly loamy fine sand with common medium distinct strong brown (7.5YR 5/6) mottles, massive |

4. *Remarks*
   - a. The organic matter content of the spodic horizon does not meet the definitive limits (over 2 percent organic matter) for Aquic Haplorthods
   - b. The organic matter content of the spodic horizon places this pedon in the Acton Series and also in the mesic soil temperature class. Pedons of the Waumbek series appear to be more prevalent in the Bartlett Experimental Forest; they belong to the frigid soil temperature class.
   - c. Profile described by Pilgrim, Viera and Reiske

## SOIL NUMBER 4

1. *Miscellaneous Plot Data*
   - a. Location — Bartlett Experimental Forest Compartment 18
   - b. Slope — 12 percent
   - c. Aspect — N 5°W
   - d. Elevation — 870 feet
   - e. Landform — Gently rolling to steep and hilly uplands of the White Mountains
   - f. Parent material — Moderately coarse textured glacial till of late Wisconsin age

2. *Soil Classification*
   a. Placement in New Soil Classification System
      (1) Subgroup — Typic Haplorthods
      (2) Family — Coarse loamy, mixed, frigid
      (3) Series — Berkshire
   b. Placement in 1938 Soil Classification System: Podzol
   c. Drainage class — Well drained

3. *Soil Description*
   Berkshire very stony fine sandy loam (all colors for moist soil)

| *Horizon* | *Depth (inches)* | *Description* |
|---|---|---|
| 01 | 3-2.5 | Loose leaf litter |
| 02 | 2.5-0 | Black (10YR 2/1) humus |
| A2 | 0-2 | Light brownish gray (10YR 6/2) fine sandy loam |
| B21h | 2-3 | Black (5YR 2/1) loamy fine sand |
| B22ir | 3-5 | Dark red (2.5YR 3/6) loamy fine sand |
| B23 | 5-9 | Strong brown (7.5YR 5/6) loamy fine sand |
| B24 | 9-13 | Yellowish brown (10YR 5/6) loamy fine sand |
| B3 | 13-24 | Light yellowish brown (2.5Y 6/4) fine sandy loam |
| C1 | 24-44 | Light brownish gray (2.5Y 6/2) and light yellowish brown (2.5Y 6/4) gravelly fine sandy loam, massive |
| C2 | 44-48 | Light brownish gray (2.5Y 6/2) gravelly fine sandy loam, massive |

4. *Remarks*
   a. Profile described by Pilgrim, Viera and Reiske

## SOIL NUMBER 11

Note: Because of the high water table, this soil profile was not observed throughout the 40-inch control section. Therefore, no *firm* classification can be given for this soil.

1. *Miscellaneous Plot Data*
   a. Location — Bartlett Experimental Forest, Compartment 16
   b. Slope — 10 percent
   c. Aspect — N 30°W
   d. Elevation — 1,050 feet
   e. Landform — Depressions in the gently rolling to hilly uplands of the White Mountains
   f. Parent material — Not determined

2. *Soil Classification*
   a. Placement in New Soil Classification System: not determined
   b. Placement in 1938 Soil Classification System: Probably Low Humic Gley
   c. Drainage class — Poorly drained

3. *Soil Description* (All colors for moist soil)

| *Horizon* | *Depth (inches)* | *Description* |
|---|---|---|
| 01 | 3.5-3 | Loose leaf litter |
| 02 | 3-0 | Very dark brown (10YR 2/2) humus |
| A2g | 0-8 | Olive gray (5Y 5/2) sandy loam |
| Bg | 8-18 | Mottled gray (5Y 5/1), light olive brown (2.5Y 5/4) and brownish yellow (10YR 6/8) loamy sand, massive |

4. *Remarks*
   a. Water table at 18 inches
   b. Parent material appears to be water-soaked glacial till
   c. Profile described by Pilgrim and Reiske

## SOIL NUMBER 15

1. *Miscellaneous Plot Data*
   - a. Location — Bartlett Experimental Forest, on the boundary of Compartments 25 and 26.
   - b. Slope — 3 percent
   - c. Aspect — Flat
   - d. Elevation — 1,000 feet
   - e. Landform — Nearly level to gently sloping glaciofluvial deposits in the upland areas of the White Mountains
   - f. Parent material — Coarse textured glaciofluvial material of late Wisconsin age

2. *Soil Classification*
   - a. Placement in New Soil Classification System
     - (1) Subgroup — Aquic Haplorthods
     - (2) Family — Sandy, siliceous, frigid
     - (3) Series — Croghan
   - b. Placement in 1938 Soil Classification System: Podzol
   - c. Drainage class — Moderately well drained

3. *Soil Description*

Croghan loamy fine sand (all colors for moist soil)

| *Horizon* | *Depth (inches)* | *Description* |
|---|---|---|
| 011 | 14-13 | Loose litter |
| 012 | 13-12 | Black (5YR 2/1) |
| 021 | 12-5 | Very dusky red (2.5YR 2/2) humus |
| 022 | 5-0 | Black (N 2/) humus |
| A2 | 0-3 | Brown (7.5YR 5/2) loamy fine sand |
| B21h | 3-5 | Black (N 2/) medium sand |
| B22ir | 5-8 | Dark reddish brown (2.5YR 3/4) and red (2.5YR 4/6) medium sand |
| B23ir | 8-17 | Yellowish red (5YR 4/6) and strong brown (7.5YR 5/6) fine sand |
| B24 | 17-29 | Brownish yellow (10YR 6/6) medium sand, with few medium distinct (10YR 7/1) mottles, single grain, loose |
| B3 | 29-36 | Matrix light yellowish brown (2.5Y 6/4) loamy fine sand with common medium faint light brownish gray (2.5Y 6/2) mottles |
| C1 | 36-40 | Mottled light gray (10YR 7/2) and reddish yellow (7.5YR 6/6-6/8) medium sand, single grain |
| C2 | 40-45 | Matrix light yellowish brown (2.5Y 6/4) and light brownish gray (2.5Y 6/2) loamy sand, with streaks of reddish yellow (7.5YR 6/8), massive |

4. *Remarks*
   - a. The total thickness of the 01 and 02 horizons of this pedon may not be representative for the Croghan series in New Hampshire. A thickness of 2 to 6 inches is probably more typical.
   - b. Profile description by Pilgrim, Viera, and Reiske

## SOIL NUMBER 17

1. *Miscellaneous Plot Data*
   - a. Location — Bartlett Experimental Forest, Compartment 22
   - b. Slope — 20 percent
   - c. Aspect — N 60°E
   - d. Elevation — 1,300 feet
   - e. Landform — Moderately sloping to hilly uplands of the White Mountains
   - f. Parent material — Moderately coarse textured glacial till of late Wisconsin age

2. *Soil Classification*
   - a. Placement in New Soil Classification System
     - (1) Subgroup — Typic Fragiorthods
     - (2) Family — Sandy, mixed, frigid[4b]
     - (3) Series — Becket
   - b. Placement in 1938 Soil Classification System: Podzol
   - c. Drainage class — Well to moderately well drained

3. *Soil Description*

Becket extremely stony sandy loam (all colors for moist soil)

| *Horizon* | *Depth (inches)* | *Description* |
|---|---|---|
| 011 | 1-.5 | Loose leaf litter |
| 012 | .5-0 | Black (10YR 2/1) humus |
| B2ir | 0-2 | Dark reddish brown (5YR 3/2) sandy loam |
| B&A | 2-24 | Yellowish brown (10YR 5/6) and 10YR 5/8) and dark brown (10YR 4/3) loamy sand |
| C1x | 24-37 | Mottled gray (10YR 6/1), dark brown (7.5YR 4/4) and light brownish gray (2.5Y 6/2) loamy sand, weak medium platy structure |
| C2 | 37-47 | Matrix grayish brown (2.5Y 5/2) loamy sand with common fine and medium distinct strong brown (7.5YR 5/6) and dark brown (7.5YR 4/4) mottles, massive |

4. *Remarks*
   - a. The profile described is on a tree throw mound which is typical of microrelief in this area. The B&A horizon represents a mixing of the B and the A horizons.
   - b. The May 1965 placement of Becket is in the coarse loamy textural family.
   - c. Profile described by Pilgrim, Viera and Reiske

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by G. R. Trimble, Jr.
and Donald W. Seegrist

# EPICORMIC BRANCHING

## On Hardwood Trees Bordering Forest Openings

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WARREN T. DOOLITTLE, DIRECTOR

## The Authors

G. R. TRIMBLE, JR., is timber-management project leader for the USDA Forest Service's Northeastern Forest Experiment Station at its Timber and Watershed Laboratory at Parsons, West Virginia. He received his forestry training at the University of Maine. He worked for a number of years in watershed management problems throughout much of the northeastern United States.

DONALD W. SEEGRIST is a biological statistician at the Northeastern Forest Experiment Station, Upper Darby, Pa. He graduated from George Washington University, Washington, D. C., in 1953 with a bachelor of science degree in zoology. He received his master's degree in 1959 and his Ph.D. degree in zoology in 1965 at the University of California, Berkeley. In 1963, he joined the U. S. Forest Service as a biological statistician at the Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif. In 1968 he joined the biometrics staff at the Northeastern Forest Experiment Station.

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# EPICORMIC BRANCHING

## On Hardwood Trees Bordering Forest Openings

**Abstract**

Epicormic branching in hardwoods can degrade logs and reduce the dollar returns from growing trees. A study made around clearcut openings of various sizes showed that the following variables were related to the degree of epicormic branching on trees bordering the openings: size of opening, species, tree dominance class, exposure of tree bole, and position on tree bole.

Common and scientific names of species referred to in this study:

| | |
|---|---|
| Basswood | *Tilia* L. |
| Beech, American | *Fagus grandifolia* Ehrh. |
| Birch, sweet | *Betula lenta* L. |
| Cherry, black | *Prunus serotina* Ehrh. |
| Gum, black | *Nyssa sylvatica* Marsh. |
| Hickory | *Carya* Nutt. |
| Maple, red | *Acer rubrum* L. |
| Maple, sugar | *Acer saccharum* Marsh. |
| Oak, chestnut | *Quercus prinus* L. |
| Oak, northern red | *Quercus rubra* L. |
| Oak, white | *Quercus alba* L. |
| Sassafras | *Sassafras albidum* (Nutt.) Nees. |
| Sourwood | *Oxydendrum arboreum* (L.) DC |
| Yellow-poplar | *Liriodendron tulipifera* L. |

## INTRODUCTION

EPICORMIC BRANCHING in hardwoods can degrade logs and reduce the dollar returns from growing trees. A study was made to investigate the effect of opening size on epicormic branching. This information is needed because group selection cutting and patch cutting with area control — both of which create small openings in the forest— are important methods of regeneration. And the creation of such openings in hardwood stands triggers epicormic branching on border trees.

In addition to studying the effects of opening size on epicormic branching, we also examined variables that previous research had shown to affect epicormic branching.

## DESCRIPTION OF AREA

The study was made in the Central Appalachians on the Fernow Experimental Forest near Parsons, West Virginia. Elevation of the study areas is about 2,500 feet. Plot slopes vary from gentle to very steep. Soils are medium-textured, well-drained, and derived from sandstone and shale. The Experimental Forest has a rainy and cool climate with a well-distributed annual rainfall of about 57 inches.

The study was made in areas that fell into two site-quality groups: one is a very good site in terms of the oak site scale *(Schnur 1937)*—site index about 75: and the other is a fair site—site index about 60. The dominating species on the better sites were sugar maple, yellow-poplar, northern red oak, black cherry, basswood, hickory, beech, and sweet birch. On the area of lower site quality, the most numerous species were chestnut, white, and red oaks; red maple; sweet birch; black gum; sassafras; and sourwood.

The stands were second growth about 60 years old; the better sites contained an admixture of old-growth stems residual from the original cutting. At study inception, all stands were unmanaged and well-stocked.

## STUDY METHODS

### Plot Layout and Measurements

Circular plots of different diameters were clearcut to specific dimensions. The smallest plots—50 feet in diameter—approximated the kind of openings that would be created by selection cutting if a couple of large trees were removed; the largest plots—250 feet in diameter — were expected to provide the kind of border environment created by large clearcuts.

The following tabulation shows the number and sizes of openings studied:

| *Opening diameter (feet)* | *Area (acres)* | *Number of openings* | |
|---|---|---|---|
| | | *Good site (s.i. 75)* | *Fair site (s.i. 60)* |
| 50 | 0.045 | 9 | 9 |
| 100 | .180 | 9 | 0 |
| 150 | .406 | 9 | 9 |
| 200 | .721 | 9 | 0 |
| 250 | 1.127 | 9 | 9 |
| | Total | 45 | 27 |

We were able to cut the plots, as measured from tree bole to tree bole, fairly close to intended size. The canopy openings were smaller than the plots measured on the ground between tree boles because of branch overhang. After cutting, some of the canopy openings for 50-foot plots were less than 20 feet across.

In the dormant season immediately before the openings were logged, the border-tree samples were designated and numbered. After logging, the sample-tree bole was divided into an exposed and an unexposed half (the exposed half faced into the opening); and this division was indicated by paint lines on the lower trunk.

The following measurements were taken for each sample tree: species, d.b.h., dominance class (taken before logging), number of half

logs, and the number of existing established branches by half-log positions on both the exposed and unexposed faces. Only trees over 5.0 inches d.b.h. were taken as samples, and most of the trees were 10 inches d.b.h and larger. Total log height was based on estimates of potential log height—that is, length of clear stem to crown.

In the dormant season after the five growing seasons, we repeated a count of branches by half logs, eliminating those branches that had existed at the first count. We based our analyses of epicormic branches on the residual number.

We terminated the study at the end of 5 years and examined the study results.

### Analysis

Because previous research has shown that epicormic branching is affected by these variables, we stratified the data on the sample trees by species, tree dominance class (dominant and codominant, 1 and 2; intermediate and suppressed, 3 and 4), and site quality (site index 75 and 60). We also stratified the data by the numbers of half logs in the tree and by opening size—the variable of primary interest.

By dividing the sample trees into so many strata, we greatly reduced the number of trees in each stratum. The less common species were not represented in many strata. Also, the smaller the opening was, the shorter the total length of border was; therefore there were fewer sample trees in the small plots.

For each stratum, we computed the number of sample trees and the mean and the variance of the number of epicormic branches on the exposed and unexposed faces for each half-log position.

The data showed that the variance was a function of the mean—the higher the mean, the higher the variance. Because the variance was not constant and some strata had no or few trees, we decided not to use analysis of variance techniques to test hypotheses about the strata means. Instead we examined the means for expected relationships. When the pattern of particular subsets of means were as expected, we took this as evidence of factor effects.

## RESULTS

### Effect of Opening Size

The effect of opening size on the occurrence of epicormic branching was measured, using means of epicormics for the exposed faces of border trees.

Because epicormic branching on the tree bole was previously known to increase with height above the ground, and because all trees did not have the same log height (they varied from 1½ to 3½ logs), it was necessary to make comparisons for similar sections of the tree bole. We therefore counted the branches in the top 16 feet of the bole. We justified this on two bases: (1) Because the upper bole branches more freely, it is a more sensitive indicator of factors that cause epicormic branching; and (2) the frequency of branching on the upper log seemed similar for trees of different total log height (table 1).

We first compared the epicormic branch means of similar tree groups in the smallest (50-foot) versus the largest (250-foot) openings (table 2). The comparisons we made were as follows: chestnut oak, site index 60, groups 1, 2 (table 2) had a mean of 2.16 epicormic branches for 12 trees bordering 50-foot openings and a mean of 4.16 sprouts for the 41 trees bordering the 250-foot opening. Of the 19 groups with sample trees in both sizes of openings, 17 had higher means for the 250-foot opening. The 10 groups of heavily sprouting species (red, white, and chestnut oak; black cherry; and basswood) all showed more sprouting in the 250-foot

Table 1. — *Average number of epicormic branches in the upper two 8-foot sections of chestnut oak trees of different log height (site index 60). Number of sample trees in parentheses.*

| 1½-log trees | 2-log trees | 2½-log trees |
|---|---|---|
| DOMINANT AND CODOMINANT | | |
| (*5*) | (*16*) | (*19*) |
| 0.6 | 1.6 | 1.3 |
| 3.0 | 2.8 | 2.6 |
| INTERMEDIATE AND OVERTOPPED | | |
| (*7*) | (*13*) | |
| 1.2 | 0.7 | — |
| 2.0 | 1.9 | — |

Table 2. — *Average number of epicormic branches on the exposed face of the upper log for openings of different sizes*

| Groups[a] | Diameter of the opening, in feet | | | | |
|---|---|---|---|---|---|
| | 50 | 100 | 150 | 200 | 250 |
| Chestnut oak — 60 — 1,2 | 2.16 (12)[b] | — (0) | 2.16 (57) | — (0) | 4.16 (41) |
| Chestnut oak — 60 — 3,4 | 2.42 (14) | — (0) | 3.43 (21) | — (0) | 2.81 (21) |
| White oak — 60 — 1,2 | — (0) | — (0) | 2.33 (9) | — (0) | 5.00 (15) |
| White oak — 60 — 3,4 | 5.67 (3) | — (0) | 7.50 (2) | — (0) | 6.78 (9) |
| Red oak — 60 — 1,2 | 3.78 (9) | — (0) | 6.07 (16) | — (0) | 5.42 (33) |
| Red oak — 60 — 3,4 | 3.40 (5) | — (0) | 10.00 (7) | — (0) | 6.11 (9) |
| Red oak — 75 — 1,2 | 5.50 (2) | 2.80 (5) | 2.00 (10) | 6.23 (22) | 6.05 (21) |
| Red oak — 75 — 3,4 | 4.00 (4) | 1.00 (1) | 4.80 (5) | 6.00 (8) | 7.71 (7) |
| Black cherry — 75 — 1,2 | .00 (9) | .50 (10) | 3.69 (13) | .83 (6) | 2.39 (18) |
| Black cherry — 75 — 3,4 | — (0) | 1.00 (2) | 2.00 (1) | .50 (2) | 3.00 (3) |
| Basswood — 75 — 1,2 | 1.50 (6) | 1.91 (11) | 5.37 (24) | 10.50 (2) | 3.82 (35) |
| Basswood — 75 — 3,4 | 2.86 (7) | 4.67 (12) | 4.00 (16) | — (0) | 6.18 (27) |
| Yellow-poplar — 75 — 1,2 | 1.45 (11) | 1.00 (25) | 1.22 (33) | 1.57 (21) | 1.21 (33) |
| Yellow-poplar — 75 — 3,4 | 1.00 (2) | 1.67 (6) | 2.78 (9) | 1.67 (6) | 1.44 (9) |
| Sweet birch — 75 — 1,2 | — (0) | 1.14 (7) | .00 (2) | .00 (2) | .33 (6) |
| Sweet birch — 75 — 3,4 | .60 (5) | .67 (3) | .36 (14) | 1.92 (12) | .94 (17) |
| Beech — 75 — 1,2 | .80 (5) | .75 (4) | 1.12 (17) | 1.11 (9) | .82 (22) |
| Beech — 75 — 3,4 | 1.00 (1) | .33 (3) | 3.90 (10) | 1.00 (2) | 2.87 (15) |
| Sugar maple — 75 — 1,2 | .18 (11) | .28 (18) | .19 (21) | .50 (2) | .32 (31) |
| Sugar maple — 75 — 3,4 | 4.50 (2) | 1.56 (9) | 2.42 (12) | 1.80 (5) | 2.46 (30) |
| Red maple — 60 — 1,2 | .33 (3) | — (0) | .33 (3) | — (0) | 1.80 (10) |
| Red maple — 60 — 3,4 | 2.08 (12) | — (0) | 3.66 (24) | — (0) | 3.31 (32) |

[a] Species — site index — crown class (1 and 2 are dominant and codominant, and 3 and 4 are intermediate and overtopped).
[b] Number of sample trees in parentheses.

openings than in the 50-foot openings. This is strong evidence that epicormic branching is affected by opening size.

We then established, for openings of all size classes, the proportion of instances where the larger opening produced more branches (table 3). We used only the heavily sprouting species groups from table 2. One expects the proportion to be close to 1.0 if the effect of opening size is large. If there is no effect of opening size, the proportion should average 0.5. The proportions in table 3 indicate that there is little or no difference among 150-, 200-, and 250-foot openings. The effects of 50- and 100-foot openings are likewise somewhat alike. The largest increase in epicormic branches is apparently between 100- and 150-foot openings.

Table 3. — *Proportion of instances where larger openings produced a greater mean number of epicormic branches. Comparison based on means (table 1) of heavy branching species*

| Smaller opening size, in feet | Larger opening size, in feet | | | |
|---|---|---|---|---|
| | 100 | 150 | 200 | 250 |
| 50 | 0.60[a] | 0.80 | 1.00 | 1.00 |
| 100 | — | .67 | .80 | 1.00 |
| 150 | — | — | .60 | .50 |
| 200 | — | — | — | .50 |

[a] In the 5 comparisons involved, means were greater for the 100-foot opening in 3 of the cases, thus % = 0.60.

## Effect of Species

It has long been recognized that tree species differ in their potential to produce epicormic branches. In a previous study of border-tree sprouting, Smith *(1966)* rated nine species of Appalachian hardwoods for this characterstic. Our study supports Smith's ratings and expands the list to 12 species.

To measure species differences, we compared the average number of epicormic branches on the exposed face of the upper log (table 2). We used the available means from trees bordering the 150-, 200-, and 250-foot plots. As a result of this evaluation, we came up with a ranking in which the species were rated in descending order of potential for branching.

Shown below by broad species groups is our list, together with Smith's list and a subjective combination of the two. Susceptibility to branching differs less within each group than it does between groups:

| *Number of branches* | *Our study* | *Smith's list* | *Combination* |
|---|---|---|---|
| Very many .... | Red oak<br>White oak | White oak | White oak<br>Red oak |
| Many ..... | Basswood<br>Black cherry<br>Chestnut oak | Black cherry<br>Red oak<br>Chestnut oak | Basswood<br>Black cherry<br>Chestnut oak |
| Few ..... | Beech<br>Yellow-poplar<br>Red maple<br>Sugar maple<br>Sweet birch | Hickory<br>Yellow-poplar<br>Red maple<br>Sugar maple | Beech<br>Hickory<br>Yellow-poplar<br>Red maple<br>Sugar maple<br>Sweet birch |
| Very few ..... | — | White ash | White ash |

### Effect of Tree Dominance

Previous studies on the Fernow Experimental Forest have shown that after release, more epicormic branching occurred on intermediate and overtopped trees than on dominant and codominant trees *(Wahlenberg 1950, Smith 1965)*.

We compared dominant and codominant trees to intermediate and overtopped trees (table 2). We compared trees bordering 150-, 200- and 250-foot openings. In 22 of 28 comparisons, the intermediate and overtopped trees had more epicormic branches on the exposed face of the upper log than the dominant and codominant trees.

For example, yellow-poplar and sugar maple on sites with an index of 75 had higher epicormic branch means in the sub-dominant group (3 and 4) than in the dominant group (1 and 2), for the 150-, 200-, and 250-foot openings.

### Effect of Site Quality

Smith *(1966)* found more epicormic branching on chestnut oak, red oak, and white oak growing on site-index 60 areas than on site-index 75 areas. In our study, red oak was the only species common to the two sites. Only four comparisons were possible among the means in the 150-foot and larger openings (table 2). The data on the effect of site on bole sprouting were contradictory. In two of the comparisons (shown below), bole sprouting was greater on the higher site; but for the other two, it was greater on the lower site. The number of epicormic branches on the exposed faces of upper logs by opening size was:

| *Group* | *150-foot openings* | *250-foot openings* |
|---|---|---|
| Red oak — *60* — 1,2 | 6.07 | 5.42 |
| Red oak — *75* — 1,2 | 2.00 | 6.05 |
| Red oak — *60* — 3,4 | 10.00 | 6.11 |
| Red oak — *75* — 3,4 | 4.80 | 7.71 |

### Effect of Exposure of Tree Bole

Several studies have shown that on trees bordering openings, more epicormic branches appear on the side of the bole facing the opening than on the side facing into the uncut stand *(Smith 1965, Trimble and Smith 1970)*. Results of our study support these findings.

We compared the epicormic branch means of the entire length of the bole on the exposed and unexposed faces for trees bordering the 200- and 250-foot openings. The sample trees were grouped by species, site quality, crown class, and number of logs in the tree. There were 54 of these groups, and 45 of them had more epicormic branches on the exposed face than on the unexposed face.

### Effect of Position on Tree Bole

Our study results showed that epicormic branching increased with height above ground. This confirmed the results of past

work *(Jemison and Schumacher 1948, Wahlenberg 1950, Smith 1965 and 1966)*.

The exposed faces of the lower half-logs were compared to the exposed faces of the upper half-logs on border trees around the 150-, 200-, and 250-foot plots. We compared only the half-logs rather than the lower and upper full logs in order to use the data on 1½ log trees. Fifty-five out of 57 groups (table 4) averaged more epicormic branches on the upper half-log than on the lower half-log.

## DISCUSSION

The concern with epicormic branching on border trees centers on the extent to which it causes a monetary loss by degrading lumber. Unfortunately, the situation cannot be summed up simply. We can say that bole sprouting appears to be more damaging than it actually is because: (1) the heaviest sprouting is on the upper stem, but the greatest volume and value of the tree are usually in the lower log; (2) the intermediate and overtopped trees sprout the most, but the most valuable trees and those most favored for final crop trees in even-aged systems are the dominants and codominants; and (3) many small epicormic branches are short-lived and therefore unlikely to have much degrading effect.

In spite of this, where we cut openings larger than 100 feet in diameter—and unless we cut them larger than this, reproduction of intolerant species is unlikely to develop satisfactorily—we will get low-quality logs in the more susceptible bole sprouters. For example, the means of epicormic branches on the butt 16-foot log for red oak (exposed and unexposed faces combined) for the three larger openings was 6.0 for dominant and codominant trees and 8.0 for intermediate and overtopped trees. These were not the short-lived type of epicormics, but had persisted for years; and many appeared to be vigorous and permanent. Therefore, in stands composed heavily of oaks, basswood, and black cherry, it is important to maintain a low border-to-cut-acreage ratio: that is, to make clearcuts as large as possible consistent with other considerations, to reduce degrade from bole sprouting.

**Table 4.** — *Comparison of epicormic branches by position on tree bole. Average number of epicormic branches on the open face*

| Groups[a] | 150-foot opening | | 200-foot opening | | 250-foot opening | |
|---|---|---|---|---|---|---|
| | Lower half log | Upper half log | Lower half log | Upper half log | Lower half log | Upper half log |
| Chestnut oak — 60 — 1,2 | 0.05 (57)[b] | 2.16 (57) | — | — | 0.05 (41) | 4.16 (41) |
| Chestnut oak — 60 — 3,4 | .05 (21) | 3.43 (21) | — | — | .19 (21) | 2.81 (21) |
| White oak — 60 — 1,2 | .00 (9) | 2.33 (9) | — | — | .73 (15) | 5.00 (15) |
| White oak — 60 — 3,4 | 4.50 (2) | 7.50 (2) | — | — | .89 (9) | 6.78 (9) |
| Red oak — 60 — 1,2 | 1.88 (16) | 6.07 (16) | — | — | 1.64 (33) | 5.42 (33) |
| Red oak — 60 — 3,4 | 3.29 (7) | 10.00 (7) | — | — | 1.33 (9) | 6.11 (9) |
| Red oak — 75 — 1,2 | .00 (10) | 2.00 (10) | 1.36 (22) | 6.23 (22) | .62 (21) | 6.05 (21) |
| Red oak — 75 — 3,4 | 2.00 (5) | 4.80 (5) | 2.88 (8) | 6.00 (8) | 1.57 (7) | 7.71 (7) |
| Black cherry — 75 — 1,2 | .54 (13) | 3.69 (13) | .17 (6) | .83 (6) | 1.17 (18) | 2.39 (18) |
| Black cherry — 75 — 3,4 | 1.00 (1) | 2.00 (1) | .00 (2) | .50 (2) | 1.00 (3) | 3.00 (3) |
| Basswood — 75 — 1,2 | .67 (24) | 5.37 (24) | 3.00 (2) | 10.50 (2) | .91 (35) | 3.82 (35) |
| Basswood — 75 — 3,4 | .88 (16) | 4.00 (16) | — | — | 1.56 (27) | 6.18 (27) |
| Yellow-poplar — 75 — 1,2 | .12 (33) | 1.22 (33) | .14 (21) | 1.57 (21) | .18 (33) | 1.21 (33) |
| Yellow-poplar — 75 — 3,4 | .22 (9) | 2.78 (9) | .17 (6) | 1.67 (6) | .11 (9) | 1.44 (9) |
| Sweet birch — 75 — 1,2 | .00 (2) | .00 (2) | .00 (3) | .00 (3) | .00 (6) | .33 (6) |
| Sweet birch — 75 — 3,4 | .07 (14) | .36 (14) | .33 (12) | 1.92 (12) | .00 (17) | .94 (17) |
| Beech — 75 — 1,2 | .06 (17) | 1.12 (17) | .00 (9) | 1.11 (9) | .00 (22) | .82 (22) |
| Beech — 75 — 3,4 | .40 (10) | 3.90 (10) | .00 (2) | 1.00 (2) | .47 (15) | 2.87 (15) |
| Sugar maple — 75 — 1,2 | .00 (21) | .19 (21) | .00 (2) | .50 (2) | .00 (31) | .32 (31) |
| Sugar maple — 75 — 3,4 | .25 (12) | 2.42 (12) | .40 (5) | 1.80 (5) | 1.13 (30) | 2.46 (30) |
| Red maple — 60 — 1,2 | .00 (3) | .33 (3) | — | — | .10 (10) | 1.80 (10) |
| Red maple — 60 — 3,4 | .71 (24) | 3.66 (24) | — | — | .81 (32) | 3.31 (32) |

[a] Species — site index — crown class (1 and 2 are dominants and codominants; 3 and 4 are intermediate and overtopped).

[b] Number of sample trees in parentheses.

For the other species, sprouting on the lower stem of border trees is lighter. For instance, yellow-poplar averages only 0.4 branch on the butt log for dominant and codominant trees and 0.6 branch for intermediate and overtopped trees. In stands of yellow-poplar and other lightly sprouting species, the threat of epicormic branching would be appreciably less of a consideration in deciding on size of area to clearcut.

## SUMMARY

From a study of epicormic branching on 10 hardwood tree species bordering forest openings of different sizes, we determined that:

- Five years after cutting, epicormic branching was about the same for 50-foot and 100-foot openings, but was appreciably less than for openings 150 feet in diameter and larger. Branching seemed about as heavy on trees bordering the 150-foot plots as on trees bordering larger plots.
- There were large differences between species in the amount of epicormic branching.
- More epicormic branching occurred on intermediate and overtopped trees than on dominant and codominant trees.
- We had too few data to demonstrate site effect, with only red oak common to our two sites (60 and 75 site index).
- More epicormic branches appeared on the exposed faces of the border trees than on the section facing into the uncut stand.
- Epicormic branching increased with height above ground.

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by Edwin L. Lucas
and Leathern R. R. Catron

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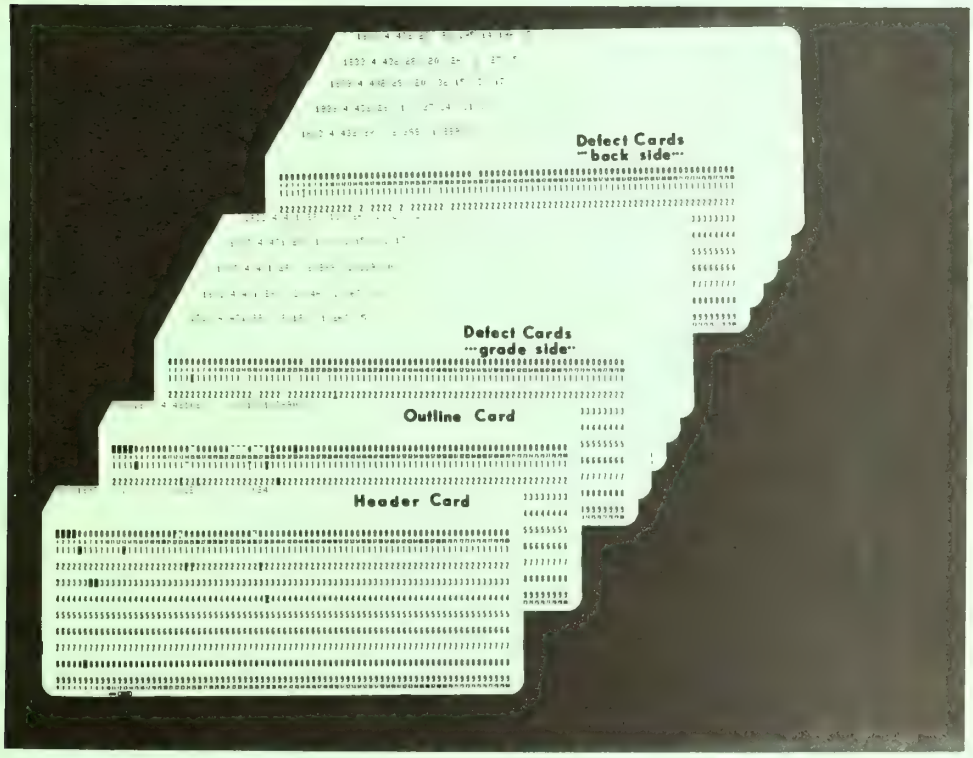


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WARREN T. DOOLITTLE, DIRECTOR

## The Authors

EDWIN L. LUCAS received his B. S. degree in forest products from Colorado State University in 1961 and his M. S. degree in forest economics from Iowa State University in 1967. At present he is an asosciate wood technologist in the hardwood product improvement project at the Forest Products Marketing Laboratory of the Northeastern Forest Experiment Station in Princeton, West Virginia.

LEATHERN R. R. CATRON is an engineering technician at the USDA Forest Service's Forest Products Marketing Laboratory in Princeton, West Virginia. He received his A. S. degree in electrical technology in 1968. He joined the Northeastern Forest Experiment Station's staff at Princeton in 1966.

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# A Comprehensive DEFECT DATA BANK For No. 2 Common Oak Lumber


## Abstract

Computer simulation of rough mill cut-up operations allows low-cost evaluation of furniture rough mill cut-up procedures. The defect data bank serves as input to such simulation programs. The data bank contains a detailed accounting of defect data taken from 637 No. 2 Common oak boards. Included is a description of each defect (location, size, and type), as well as the length and width of the board. All information is recorded on data-processing cards. Though the data bank applies directly to No. 2 Common oak, it can be used to evaluate the yields of most species of No. 2 Common lumber that are graded according to the standard rules.


## INTRODUCTION

MORE THAN HALF of the hardwood lumber produced in the sawmills of the Appalachian Region is graded No. 2 Common or lower. One-fourth of the total volume is No. 2 Common, and the volume of No. 2 Common is expected to increase during the next decade.[1, 2] New ways of converting this material into products or product parts are needed to assure future markets for this lumber. Effective research to develop new conversion procedures will require new approaches. Conventional case studies are impractical because of the difficulty in obtaining matched samples.

Computer simulation of rough mill cut-up operations allows low-cost evaluation of new manufacturing procedures. This report describes a board defect data bank for No. 2 Common oak lumber which we have compiled for use in these simulation studies. This data bank contains an extensive collection of board defect data and is available for use by researchers and wood industry firms.

[1] Goho, Curtis D., and Paul S. Wysor. 1970. Characteristics of factory-grade hardwood logs delivered to Appalachian sawmills. USDA Forest Serv. Res. Paper NE-116, 17 p., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

[2] Vaughan, C. L., A. C. Woolin, K. A. McDonald, and E. H. Bulgrin. 1966. Hardwood log grades for standard lumber. USDA Forest Serv. Res. Paper FPL-63, 52 p., illus. USDA Forest Prod. Lab., Madison, Wisc.

## THE DATA BANK

The data bank is a collection of board defect data taken from 637 No. 2 Common oak boards totaling 4,487 board feet. All data are recorded on punched cards. Included is a description of each defect by location, size, and type, as well as the length and width of the board. The data bank provides input for computer analysis of rough mill cut-up procedures.

### The Sample

In developing the data bank, our goal was to select a sample that was representative of the population of No. 2 Common oak boards. The sampling schedule used for this study

was similar to one developed by Dunmire and Englerth.[3] This schedule calls for grouping boards into seven length classes and seven width classes, a total of 49 sampling cells. The prescribed number of boards per cell was 16. Thus, the total number of boards called for by the schedule is 784 (49 x 16).

Each of the 49 sampling cells was divided into four utility groups. These utility groups, or strata, separated boards according to their clear area as follows:

| *Utility group* | *Clear area in the board[4] (percent)* | *Number of observations (boards)* |
|---|---|---|
| 1 | 50–60 | 3 |
| 2 | 61–70 | 6 |
| 3 | 71–80 | 5 |
| 4 | 81+ | 2 |

[3] Dunmire, Daniel E., and George H. Englerth. 1967. Development of a computer method for predicting lumber cutting yields. USDA Forest Serv. Res. Paper NC-15, 7 p., illus. N. Central Forest Exp. Sta., St. Paul, Minn.

[4] To be included in the calculation, a clear area must be at least 2 by 18 inches or 3 by 12 inches.

This technique emphasizes the more commonly found boards—those in which between 60 and 80 percent of the surface area is clear wood.

Our collection of 637 boards totaled over 4,400 board feet, and although it is the largest documented sample of No. 2 Common oak lumber available, we were unable to fill all cells in the schedule (table 1 ). Boards were selected from four widely dispersed mills in West Virginia and Virginia. The production runs from which our sample was taken totaled approximately 300,000 board feet. Our inability to fill all cells in the schedule was partly due to the naturally limited occurrence of very wide boards and very narrow long boards. So we believe the sample represents No. 2 Common oak lumber adequately for practical purposes (table 2).

Table 1.—*Number of 4/4 kiln dried No. 2 Common oak boards in the data bank, by length and width classes.*[a]

| Width classes (inches) | Length class (feet) | | | | | | | All lengths |
|---|---|---|---|---|---|---|---|---|
| | 4 | 5–6 | 7–8 | 9–10 | 11–12 | 13–14 | 15–16 | |
| 3–4 | 14 | 16 | 12 | 13 | 11 | 9 | 5 | 80 |
| 5–6 | 13 | 17 | 18 | 22 | 17 | 16 | 14 | 117 |
| 7–8 | 16 | 16 | 18 | 15 | 21 | 18 | 16 | 120 |
| 9–10 | 17 | 19 | 18 | 17 | 17 | 16 | 16 | 120 |
| 11–12 | 14 | 16 | 19 | 20 | 22 | 12 | 12 | 115 |
| 13–14 | 6 | 6 | 14 | 11 | 13 | 5 | 3 | 58 |
| 15+ | 2 | 2 | 5 | 5 | 6 | 4 | 3 | 27 |
| Total | 82 | 92 | 104 | 103 | 107 | 80 | 69 | 637 |

[a] In the shaded area the number of boards sampled met or exceeded the prescribed number (16) for each sampling cell.

Table 2.—*Volume of 4/4 kiln dried No. 2 Common oak boards in the data bank, by length and width classes*

[*In board feet*]

| Width classes (inches) | Length class (feet) | | | | | | | All lengths |
|---|---|---|---|---|---|---|---|---|
| | 4 | 5–6 | 7–8 | 9–10 | 11–12 | 13–14 | 15–16 | |
| 3–4 | 14 | 30 | 32 | 46 | 43 | 45 | 27 | 237 |
| 5–6 | 26 | 45 | 66 | 100 | 95 | 103 | 105 | 540 |
| 7–8 | 36 | 56 | 90 | 96 | 157 | 159 | 155 | 749 |
| 9–10 | 51 | 81 | 117 | 132 | 161 | 172 | 198 | 912 |
| 11–12 | 54 | 88 | 145 | 187 | 256 | 163 | 177 | 1,070 |
| 13–14 | 26 | 35 | 126 | 120 | 176 | 74 | 55 | 612 |
| 15+ | 10 | 13 | 51 | 65 | 93 | 71 | 64 | 367 |
| Total | 217 | 348 | 627 | 746 | 981 | 787 | 781 | 4,487 |

## Data Collection and Description

All lumber was kiln dried to a moisture content of 7 percent before defect data were collected. After kiln drying, the lumber was graded by a certified inspector of the National Hardwood Lumber Association (NHLA) using the NHLA Special Kiln Dried Rule.[5]

All defects in each board were recorded and coded by size and kind, according to the 21 defect classifications listed in table 3. In addition, the side of the board on which the defect occurred (grade side or back) was recorded. This procedure was used because the grading rules for dimension parts specify allowable defects for both the face and reverse side of parts.

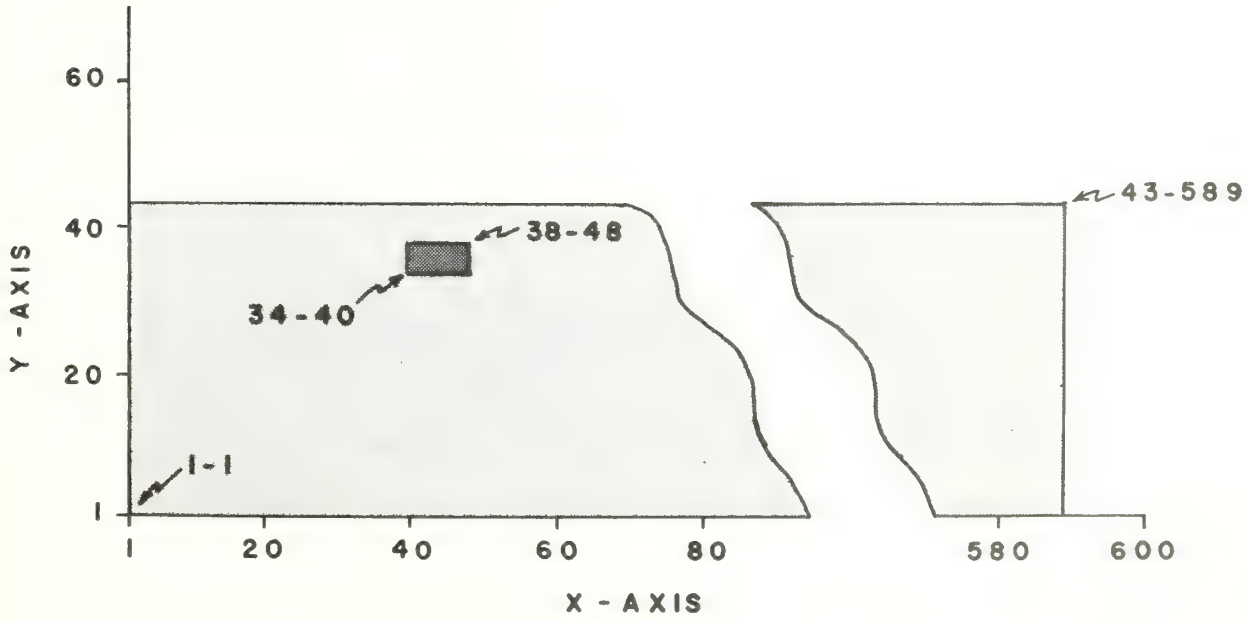
The board dimensions and the location and dimensions of each defect were recorded, using a cartesian coordinate system graduated in ¼-inch units (fig. 1). Boards were placed with the lower left corner at the point 1-1, with the width of the board along the posi-

Table 3.—*Board defect descriptions and code numbers*

| Code No. | Defect description |
|---|---|
| 001 | Mechanical damage<br>Dog hole<br>Felling notch<br>Felling tear-out |
| 002 | Void |
| 003 | Pith |
| 004 | Decay |
| 005 | Shake |
| 006 | Split |
| 007 | Machine-made split |
| 008 | Wane and scant thickness |
| 009 | Sawline |
| 010 | Bark pocket |
| 011 | Grub hole; ¼ inch and over |
| 111 | Shot worm hole; greater than 1/16 inch, less than ¼ inch |
| 211 | Pin worm hole; 1/16 inch or less |
| 012 | Unsound knot |
| 013 | Burl with bark or check |
| 014 | Surface check |
| 015 | Sound knot |
| 016 | Machine-chipped or torn grain |
| 017 | Machine snipe and tear-out |
| 018 | Incipient decay |
| 019 | Sticker stain |
| 020 | Bud trace with bark or check |
| 021 | Callus wood |

[5] National Hardwood Lumber Association. 1967. Rules for the measurement and inspection of hardwood and cypress lumber. 116 p., Chicago, Ill.

Figure 1.—The outline of a 10½ inch board 12¼ feet long is described by the points 1-1 and 43-589; the location of a defect 1 inch by 2 inches is described by the points 34-40 and 38-48.



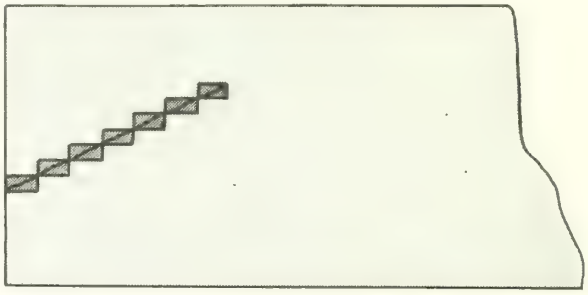
tive Y-axis and the length along the positive X-axis. Each board or defect was described as a rectangle. Each rectangle was located by its lower left and upper right corners. Thus, only two pairs of points are necessary to describe each board and each defect. For example, a board 10½ inches wide and 12 feet 3 inches long is described by the set 1-1 and 43-589.[6]

Certain large defects were treated as a series of small defects (fig. 2). This provided for a more accurate description of the defect and minimized the amount of clear wood recorded as defective.

## Data Format

All information pertaining to a board was recorded on 80-column punch cards. Each board's complete data deck contains, in order, one header card, one outline card, and one defect card for each defect in the board (fig. 3). The defect cards are arranged so

Figure 2.—To minimize the amount of clear wood recorded as defective, certain large defects were treated as a series of small defects.



[6] Note: The dash separates, in order, the "Y" and "X" units.

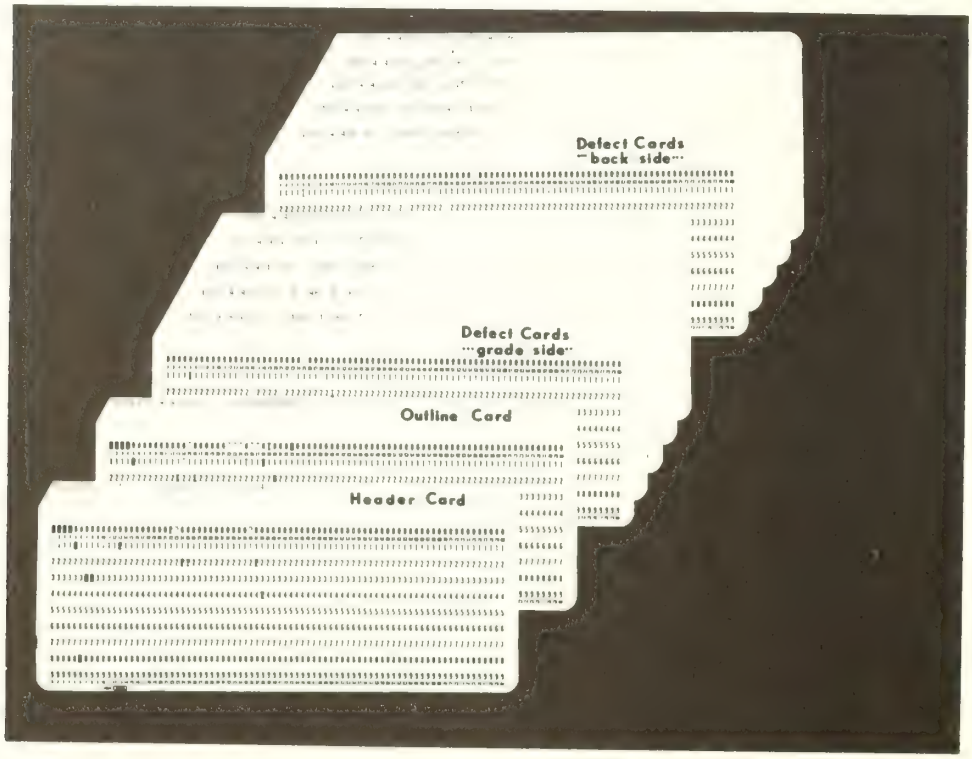



Figure 3.—Data cards for each board are arranged in the following sequence: (1) header card, (2) outline card, (3) defect cards, grade side, and (4) defect cards, back side.

that defects on the grade side of the board come before those on the back of the board. A detailed description of all information contained in the cards is in the Appendix.

## USE OF THE DATA BANK

The board defect data bank offers both researchers and industry an opportunity to develop greater efficiency in the utilization of No. 2 Common hardwood lumber. It can be used with existing rough-mill computer simulation programs to determine the yield of dimension parts for any desired cutting bill. The U. S. Forest Products Laboratory's simulation program, YIELD, is available for this use.[7] In addition, researchers at the Forest Products Marketing Laboratory (FPML) have expanded program YIELD. This expanded version allows the program to simulate processing of boards with more defects and is thus well suited for evaluating No. 2 Common lumber.

The data bank contains descriptions as well as measurements of all defects found on the boards. Thus it can be used to determine the yields of various grades of cuttings. The entire deck will give the yield of dimension parts that satisfy the clear-two-sides (C2S) grade requirement. However, because defects can be selected by size, type, and board face, yield data need not be limited to C2S cuttings. Yield figures can also be determined for other grades of dimension parts such as C1S, paint, core, and sound. This flexibility is valuable for evaluating the economics of alternate uses for No. 2 Common lumber.

While the data we have collected apply directly to No. 2 Common red and white oak lumber, their use is not limited to these species. Field tests of the Forest Products Laboratory's system for calculating dimension yields from hard maple lumber,[8] have shown that the predictions apply not only to hard maple lumber, but to most species graded by the standard rules. Thus, the results obtained by use of our data bank should be applicable to most species of No. 2 Common hardwood lumber graded according to the standard rules.

Copies of the data bank are available. The enclosed card may be used to request information on how to obtain a copy and its cost.

[7] Wodzinski, Claudia, and Eldona Hahm. 1966. A computer program to determine yield of lumber. 34 p., illus. USDA Forest Prod. Lab., Madison, Wisc.

[8] Englerth, George H., and David R. Schumann. 1969. Charts for calculating dimension yields from hard maple lumber. USDA Forest Serv. Res. Paper FPL-118. 12 p., USDA Forest Prod. Lab., Madison, Wisc.

# APPENDIX

## Description of Board Input Data[9]

I. Header Card: One card for each board.

| *Item* | *Card Column* | *Description* |
|---|---|---|
| Board number | 1–5 | Up to a five digit number to indicate board number.[10] |
| Card type | 13 | One digit number to identify the card as a header card. There will be a 1 in this column for all header cards. |
| Number of defects | 22–25 | Up to a four digit number to specify the number of defects contained in the board. |
| Number of cards | 36–38 | Up to a three digit number to specify the total number of cards pertaining to the board; the count to include the header card, outline card, and all defect cards for the board. |

II. Outline Card and Defect Card: One outline card for each board and one defect card for each defect.

| *Item* | *Card Column* | *Description* |
|---|---|---|
| Board number | 1–5 | Five digit number to indicate board number. |
| Species | 6–8 | Three digit number to identify species group: 833 red oak and 834 white oak. |
| Inspected grade | 10 | One digit number to identify the grade of the board as determined by NHLA inspector: FAS = 1, SEL = 2, No. 1 Common = 3, and No. 2 Common = 4. |
| Verified grade | 12 | One digit number to identify the grade of the board as determined by laboratory techniques. Same code as for inspected grade. |
| Card type | 13 | One digit number to identify the card as either a defect card or the board outline card: outline card = 2, a defect card = 3. |
| Board side | 14 | One digit number to indicate if the defect is on the grade side of the board (the side that the NHLA inspector uses in determining grade of the board) or on the back side: grade side = 1, back side = 2. |
| Board width | 15–17 | Three digit number indicating the width of the board to the nearest ¼ inch, i.e. a board 12 inches wide would be recorded as 048. |
| Defect code | 18–21 | Four digit number to identify the type of defect. See table 3 for a listing of the defect codes. |
| Lower left X | 22–25 | Four digit number to indicate the position of the lower X coordinate of a rectangle that would (a) enclose the board if the card is an outline card, or (b) enclose a defect if the card is a defect card. |
| Lower left Y | 26–28 | Three digit number to indicate the position of the lower Y coordinate of the rectangle. |
| Upper right X | 29–32 | Four digit number to indicate the position of the upper X coordinate of the rectangle. |
| Upper right Y | 33–35 | Three digit number to indicate the position of the upper Y coordinate of the rectangle. |
| Card number | 36–38 | Three digit number to serialize the cards of each board. |

[9] All data entries are right justified.
[10] For identification, each board was assigned a number.

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# *Deriving*
# FAIR INCENTIVES
## *for Management of Hardwood Timber Stands*

by David A. Gansner
Owen W. Herrick
David N. Larsen

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6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

DAVID A. GANSNER is leader of the Northeastern Forest Experiment Station's Regional Production Economics Research Work Unit at Upper Darby, Pa. He received his degree in forestry from the University of Missouri in 1958, a master's degree in agricultural economics from Ohio State University in 1968, and a master's degree in regional science from the University of Pennsylvania in 1970. He has been with the U. S. Forest Service since 1958.

OWEN W. HERRICK received his bachelor of science degree at Iowa State University and a master of forestry degree at Yale University. He has done graduate study in regional systems analysis at The Pennsylvania State University. At present he is a research forester in the Regional Production Economics Work Unit at the Northeastern Forest Experiment Station, Upper Darby, Pa.

DAVID N. LARSEN received his bachelor of science degree in forestry from Washington State University in 1964, a master of science degree in forest economics from Michigan State University in 1967, and a master of arts degree in regional science from the University of Pennsylvania in 1971. He joined the Northeastern Forest Experiment Station at Upper Darby, Pa., in 1967 and is a research forester in the Regional Production Economics Work Unit.

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# *Deriving*
# FAIR INCENTIVES
# *for Management of Hardwood Timber Stands*


## ABSTRACT

The authors present a practical method for deriving timber-management incentive payments and demonstrate its application in forest stands of upland hardwoods. The suggested incentive payment is based on the differences between discounted costs and returns of deliberate forest management and the "harvest and let grow" option.


TODAY WE ARE witnessing new interest in action programs designed to improve the timber productivity of private non-industrial forests. But small private woodland owners remain an apathetic clientele. Few of them believe that investments in forestry are worthwhile. As John R. McGuire (*3*), Chief of the Forest Service, recently said:

> A wealth of research studies and practical experience has made clear the fact that most owners of small forest tracts are not motivated or not able to make the investments needed to improve their forest resources. . . . The competition for the landowner's disposable income is keen—the payoffs he gets from forestry investments to meet his objectives are long delayed, and investments for some practices that would benefit the public as a whole may not necessarily appeal to the individual landowner at all. These factors preclude any likelihood of substantial progress or a high level of investment without some form of financial incentives.

Cash incentive payments apparently offer a means for persuading these owners to practice good timber management. But what constitutes a fair incentive payment? We offer a practical approach to this problem and can demonstrate its application in forest stands of upland hardwoods.

## APPROACH

"Harvest and let grow" is probably the most common approach to timber management by the private non-industrial woodland owner. If markets for his timber exist, he can sell the merchantable volume in his stand, put the money into his best capital earning opportunity — or spend it — and depend on nature to grow him a new stand of trees.

Few foresters condone this practice. But they must admit to certain undeniable advantages that it has over most recommended systems of management. The woodland owner reaps an immediate cash income, incurs no out-of-pocket costs, and foregoes the problems of risk and uncertainty associated with long-term investments in timber growing. No wonder the practice is appealing.

Because of its inherent appeal, the "harvest and let grow" option provides a logical standard for gaging the relative worth of other timber-producing alternatives. The net return to the landowner from any recommended system of timber production should be at least as great as that from the "harvest and let grow" method. If not, the owner should receive a cash payment to make up the difference. Only then would we expect him to consider the recommended system.

In this paper we consider only timber-producing alternatives and make no attempt to evaluate the potential impact of these alternatives on wildlife habitat, water yields, aesthetics, and other products and services. In cases where gains or losses in the output of other products and services are considered important and can be quantified, they should be incorporated into the calculation of incentive payments.

## APPLICATIONS

Case examples will demonstrate the use of the fair incentive payment approach. Consider these two typical situations:

- Mr. A owns a tract of upland hardwood exhibiting a history of poor timber management. Much of the stand is stocked with old cull and defective trees that are not worth managing. Without treatment, noticeable improvements in stand condition cannot be expected for several years. Mr. A's best market opportunity for capital investment is the local savings and loan association, where he earns a compound rate of return of 6 percent on deposits.
- Mr. B owns a stand of upland hardwood that is fully stocked, mainly with sound immature trees of desirable species. Proper treatment could result in a substantial increase in the yield of high-value timber. Mr. B's best market opportunity for capital investment is the local bank, which pays a compound rate of 5 percent on savings.

Suppose Mr. A and Mr. B are approached by the local service forester. This public agent wants both of them to use proven methods of sound silviculture to improve the condition and productivity of their forest tracts.

He tells Mr. A that his stand of trees is not fully utilizing its site and cannot be expected to do so for many years. The tract should therefore be regenerated as soon as possible. The resulting new stand should then be cleaned and periodically thinned so as to maximize yields and promote the rapid growth of timber to a mature stage of development.

He advises Mr. B to make an improvement

Table 1.—*Management schedule for Mr. A: treatments, costs, yields, and returns per acre*

| Year | Treatment | Treatment costs | Timber removals | Sawtimber included in timber removals | Value of removals |
|---|---|---|---|---|---|
| | | *Dollars* | *Cords* | *MBF* | *Dollars* |
| 0 | Regeneration cut | 13 | 8.6 | 1.6 | 76 |
| 10 | Cleaning | 21 | 0 | 0 | 0 |
| 30 | Commercial thinning | — | 5.0 | 0 | 12 |
| 42 | Commercial thinning | — | 5.0 | 0 | 13 |
| 52 | Commercial thinning | — | 5.1 | 0.9 | 25 |
| 62 | Commercial thinning | — | 5.8 | 1.8 | 53 |
| 70 | Harvest | — | 29.9 | 12.0 | 674 |
| | Total | 34 | 59.4 | 16.3 | 853 |

Table 2.—*Management schedule for Mr. B: treatments, costs, yields, and returns per acre*

| Year | Treatment | Treatment costs | Timber removals | Sawtimber included in timber removals | Value of removals |
|---|---|---|---|---|---|
| | | *Dollars* | *Cords* | *MBF* | *Dollars* |
| 0 | Improvement cutting | 16 | 1.0 | 0 | 0* |
| 12 | Commercial thinning | — | 5.0 | 0 | 12 |
| 22 | Commercial thinning | — | 5.0 | 1.1 | 14 |
| 32 | Commercial thinning | — | 5.0 | 1.8 | 23 |
| 42 | Commercial thinning | — | 5.1 | 2.1 | 55 |
| 50 | Harvest | — | 33.7 | 15.1 | 750 |
| | Total | 16 | 54.8 | 20.1 | 854 |

* Cut at year 0 is not operable and therefore has no market value.

cutting on his fully stocked stand immediately to provide adequate growing space for potential crop trees. The stand should then be thinned periodically to promote the rapid development and maturity of high-quality timber.

The service forester prepares a management plan for each tract. It includes a schedule of specific treatments and provides estimates of per-acre costs, yields, and returns. The examples used here are actual cases from a current study of opportunities for intensive timber management in upland hardwood stands of the Northeast.

If Mr. A follows the forester's advice, he (or his descendants) can expect to cut sound timber worth $853 from each acre of his forest tract during the next 70 years (table 1). He would spend $34 on each acre for regeneration cuttings and pre-commercial thinnings. The present net value from this proposed action, at Mr. A's best opportunity for capital investment (6 percent), would be $69 per acre.

If Mr. B adheres to the management plan, he can expect to harvest timber worth $854 from each acre of his forest tract during the next 50 years (table 2). He would spend $16 per acre for improvement cutting. The present net value from this action, at Mr. B's best opportunity for investment (5 percent), would be $73 per acre.

Now suppose each owner chooses to ignore the service forester's advice and decides instead to harvest and sell all the merchantable volume on his tract and let nature develop a new stand of timber.

If Mr. A follows this "harvest and let grow" strategy, he would reap an immediate cash income of $76 per acre. The projected value of his new stand, 70 years hence, would be $146 per acre. The present net value from "harvest and let grow", at Mr. A's best opportunity for capital investment (6 percent), would be $78 per acre.

If Mr. B follows the "harvest and let grow" strategy, he would receive $82 per acre now. And the projected value of his new stand, 50 years hence, would be $100 per acre. The present net value from this action, at 5 percent, would be $91 per acre.

For both woodland owners, the present net value from the "harvest and let grow" option would exceed the present net value from the management strategy recommended by the service forester. Thus if Mr. A and Mr. B are expected to follow the recommended forestry strategies, both should receive an incentive payment. The amount of that payment would equal the difference in net value between "harvest and let grow" and the recommended forestry strategy:

| Strategy: | *Present net value per acre to—* | |
|---|---|---|
| | *Mr. A* | *Mr. B* |
| Harvest and let grow | $78 | $91 |
| Recommended forest management | 69 | 73 |
| Difference = suggested incentive | $ 9 | $18 |

Mr. A would receive a cash payment of $9 per acre, and Mr. B would receive a payment of $18 per acre. In cases where the net value of the recommended forestry action exceeded the net value of "harvest and let grow", no incentive payment would be warranted.

## DISCUSSION

This is a practical method for deriving fair timber-management incentive payments. On-the-ground application of this technique would require realistic estimates of costs, yields, and returns for each case encountered in the field. Accurate estimates of short-run cash flows would be especially important. A small error in the estimate of a receipt (or expenditure) expected in the next few years might be critical, whereas a large error in the estimate of a receipt (or expenditure) expected several decades from now might be relatively insignificant. For example, at a discount rate of 6 percent, the present net value of a $10 error in the estimate of a value expected 10 years from now would be $5.58. But the present net value of a $100 error in the estimate of a value expected 70 years from now would be only $1.69.

The incentive payments yielded by this approach can be considered fair, at least in a strict economic sense. But there is no guarantee that these payments would induce woodland owners to practice forestry. The individual's decision to follow recommended systems of timber production will depend on a number of factors, not the least of which are his willingness to wait for a return on his investment and his willingness to produce a stand of high-quality trees for future generations.

Receipts forthcoming in the far distant future are likely to have little impact on his decision to manage. If Mr. A decided to "harvest and let grow", he would receive an immediate income of $76 per acre. If he chose instead to follow the management schedule proposed by the service forester, he would still get the $76. But he would also spend $13 per acre for regeneration cuttings. When the incentive payment of $9 is added, his net return at the outset of this venture would be $72 per acre, which approaches but still falls short of the $76 that would be yielded by the "harvest and let grow" strategy. A short-run analysis of Mr. B's alternatives produces a similar outcome.

In any case, the incentive payment would enhance the economic desirability of the recommended forestry strategy. And the woodland owner who practices good silviculture can look forward (with a high degree of certainty) to substantial improvements in the quality and productivity of his timber tract.

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# FISHERMEN EXPECTATIONS and PAY-LAKE PROFITS

by George H. Moeller
and John Engelken

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NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## THE AUTHORS

GEORGE H. MOELLER is a research forester in recreation with the Northeastern Forest Experiment Station's research project at the State University College of Environmental Science and Forestry at Syracuse University, Syracuse, N. Y. He received his B.S. and M.S. degrees in forest economics from Southern Illinois University. He joined the USDA Forest Service in September 1965 and has served at the Syracuse recreation project since March 1968.

JOHN ENGELKEN is an assistant professor at the State University of New York College of Environmental Science and Forestry at Syracuse University, Syracuse, New York. He received his B.S. degree in forestry from Utah State University. He joined the college staff in 1952 and has served as director of the Heiberg Memorial Forest since 1959.

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# FISHERMEN EXPECTATIONS and PAY-LAKE PROFITS


## ABSTRACT

Personal interviews with licensed fishermen in Central New York State were used to determine characteristics of fishermen who are willing to pay to fish. Willingness to pay was related to aspects of the fishing experience that most strongly influenced fishing enjoyment. Sixty-two percent of the respondents expressed a willingness to pay for a quality fishing experience. Study results suggest that much instability in the pay-lake fishing market may be due to the failure of individual operators to adequately consider all of the costs involved in providing quality fishing experiences.


PEOPLE WHO run commercial recreation businesses have responded quickly to the demands for outdoor recreation services and facilities. Yet most of the growth in commercial outdoor recreation has occurred haphazardly, without benefit of information about consumer markets. This has been true of commercial pay-lake (a pond or lake where people pay for the privilege of catching fish) enterprises.

Profits from commercial pay-lakes have seldom met owner expectations. Case studies have shown that pay-lake operators seldom make enough profit to pay for their own labor (*Jordan 1962; Owens 1964; Street 1967*). Yet, this study and other similar ones indicate that a significant proportion of fishermen say that they are willing to pay to fish. Surveys of licensed fishermen in the Northeastern States revealed that 33 to 50 percent were willing to pay a landowner for the opportunity to fish on his land (*Bevins et al. 1968*).

Why then have commercial pay-lake operations met with limited financial success? Part of the instability in the pay-lake market may be due to an inadequate consideration of what the commercial operator can profitably provide as opposed to what people expect from and are willing to pay for pay-lake fishing experiences.

## THE STUDY

The information presented here was obtained from personal interviews conducted during the summers of 1969 and 1970 with 95 adult licensed fishermen. Respondents were randomly sampled from anglers who fished in three ponds managed by the State University of New York College of Environmental Science and Forestry. Each fisherman was interviewed to determine his past fishing experience, socio-economic background, and fishing expectations.

The three ponds are located 20 miles south of Syracuse, New York, on the Heiberg Memorial Forest. In addition to student instruction, the ponds are used for limnological and fisheries research. The College fishing

project began in 1965. Since then the ponds have provided 1,405 days of fishing for 543 fishermen.

The ponds, ranging in size from 5 to 14 acres, are located at the base of rolling terrain and are surrounded by conifer and deciduous trees. In their setting they look more natural than man-made. Fishermen often comment on the enjoyment they receive from the natural beauty of the pond surroundings.

Fingerlings, 2 to 4 inches long, are stocked annually, with alternate stockings of brook and rainbow trout. The number of fish caught and the time required to catch fish varies considerably from pond to pond, over the season, and from year to year. During the first 4 years of the fishing project, fish caught averaged 11.8 inches in length and 12.4 ounces in weight. Fishermen who participated in the College project fished for an average of 3.5 hours each time.

These fishermen were required to provide information about their catch and were encouraged to give information about their fishing experience. Pond fishing pressure is controlled through permits, which are issued on a first-come, first-served basis, and are returned before leaving the pond. Written on the fishing permit is the question, "If the Heiberg ponds were under private ownership, what is the maximum amount you would be willing to pay for a permit that would allow you to catch, 3, 5, and 10 trout, recognizing that the permit would not guarantee catch success?" Answers to the question were provided by 350 anglers.

## STUDY RESULTS

### Description of Study Group

Respondents were all residents of central New York State. They traveled a one-way distance of less than 30 miles to the Heiberg ponds. Males accounted for 87 percent of the study group. The anglers averaged 42 years in age. They averaged 17 fishing years experience and had spent an average of 14 days fishing during the year before the survey. Fifty percent did most of their fresh-water fishing in ponds and lakes, 37 percent fished in rivers and streams, and 13 percent fished about equally in both. Twenty-eight percent of the respondents owned fishing boats, and 37 percent owned outboard motors. Fourteen percent of the fishermen surveyed had previously paid to fish in a commercial pay-lake.

Professional people made up the largest occupational group (25 percent), followed by managers and service workers (12 percent each). Craftsmen, clerical workers and housewives each made up 8 percent of the sample. Students accounted for 14 percent, and retired people accounted for 8 percent. The remaining 5 percent were laborers. Fishermen in the work force worked an average of 43 hours per week during the summer and had an average of 20 hours of free time per week.

Fishermen from whom data were collected were sampled from among licensed fishermen who agreed to participate in the Heiberg research project by obtaining a permit and providing information about their catch. Therefore, a question may be raised about whether or not the group surveyed was representative of the general fishing public. In terms of background characteristics—age, sex, fishing experience, and occupation—the survey group compares closely with characteristics of licensed, freshwater fishermen found in surveys of the general fishing public (*Bevins et al. 1968*).

### Comparison Between Willingness-To-Pay Groups

Fishermen were divided into two groups based on their willingness to pay for pond fishing. Statistical tests were run to determine the differences between the two groups in background characteristics and fishing expectations. Results of these comparisons should be useful to pay-lake operators in directing their marketing programs toward those fishermen who are most likely to pay to fish.

### Fisherman Characteristics

Significant differences were found to exist between characteristics of fishermen who would and those who would not pay to fish. Fishermen over 40 years of age were less

willing to pay to fish than younger anglers. While 70 percent of the younger group said they would pay, only 53 percent of the older fishermen felt the same way.

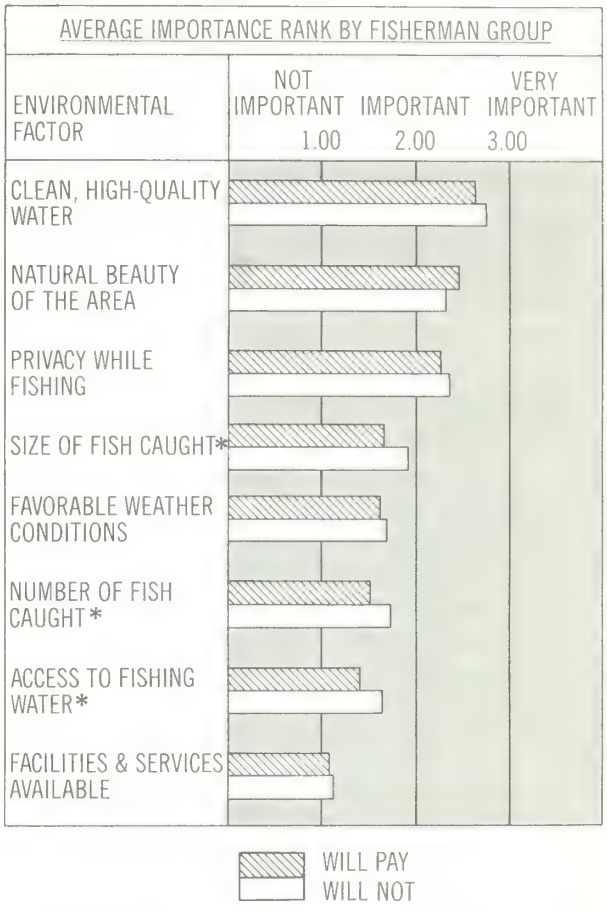
Educational background was also related to willingness to pay. Forty-seven percent of the anglers with high school degrees or less said they would pay to fish as compared to 73 percent of fishermen who had attended college.

The amount of free time available—time not devoted to work, household chores, or family responsibilities—was significantly related to a fisherman's willingness to pay. Seventy-three percent of fishermen having an average of 20 hours or less of free time per week were willing to pay as compared to 47 percent of those having more free time.

Whether or not a fisherman had previously paid to fish apparently had an influence on his willingness to pay in the future. Of those fishermen who had previously paid to fish, 92 percent were willing to pay, while only 49 percent who had not previously paid felt this way.

From a marketing standpoint, fisherman characteristics that were not associated with willingness to pay may be more important that those that were. For example, it was felt that a fisherman's background residence—where he lived during childhood—would have a relationship to willingness to pay. However, study data did not support this notion. A fisherman's occupation, the amount of time devoted to his primary job, the number of years he had fished, and the type of fishing equipment he owned and whether he had previously fished in the Heiberg ponds had no relationship to his willingness to pay.

Figure 1.—What fishermen look for in a fishing experience and their willingness to pay to fish.




*Significant differences between groups at the .05 level, using the chi square test.

## Fishing Expectations

Fishermen were asked to rank the relative importance value of eight factors that influenced their enjoyment of a typical, 1-day fishing trip (fig. 1). Although the factors did not include all of the many elements that influence fishing enjoyment, aspects of the fishing experience that can be partially influenced by pay-lake operators were considered.

Regardless of their attitude toward payment of a fee, fishermen consistently ranked three factors—clean water, natural beauty of the fishing area, and privacy—as having the greatest influence on their fishing enjoyment (fig. 1).

Size and number of fish caught were ranked fourth and sixth, respectively, in overall importance by both groups of fishermen. However, there was a significant difference between the magnitude of the two rankings. Fishermen who were not willing to pay a fee ranked the size and number of fish caught as being more important to their fishing enjoyment than fishermen who were willing to pay. Access to fishing waters, seventh in overall importance, was more important to those fishermen who

would not pay to fish than to those who would pay (fig. 1).

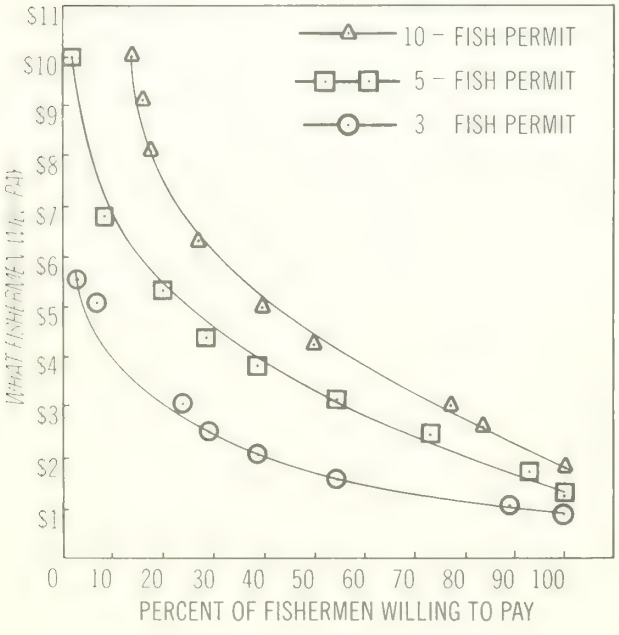
Few differences were found in the way the two groups ranked the eight factors. Therefore, fishermen desire much more from their fishing experience than merely catching fish. They want quality fishing experiences in uncrowded, beautiful, natural surroundings. Whether or not this kind of experience can be provided at a profit depends on how much fishermen are really willing to pay for such an experience and on whether other fishing areas are available that provide such an experience at a lower or no cost.

### Amount Fishermen are Willing to Pay

Three out of five fishermen in this study said that they would be willing to pay for a permit that would allow them to catch 3, 5, or 10 trout, with no guarantee of success. Data summarized from 350 permits were used to develop price frequency curves for each of the three permit levels. These curves show the percentage of fishermen who said they would pay a specific amount or more for each permit (fig. 2).

All willing fishermen said that they would pay at least $0.50 for a 3-fish permit, $1.00 for a 5-fish permit, and $1.75 for a 10-fish permit. Half of them were willing to pay at least $1.50 for a 3-fish permit, $3.00 for a 5-fish permit, and $4.50 for a 10-fish permit. Forty percent of the fishermen stated that they would pay $5.00 or more for a 10-fish permit, and 15 percent indicated that they would pay $10.00 or more, even without the assurance of catching fish (fig. 2). It should be emphasized that the fishermen were not only reacting to their willingness to pay a fee to catch fish, but to their willingness to pay for the total fishing experience.

Figure 2.—Amount fishermen are willing to pay for 3-, 5-, and 10-trout permits. Data summarized from response of 350 licensed fishermen who said they would pay to catch stocked trout in the Heiberg Forest ponds, with no guarantee of catch success.




## DISCUSSION

Pay-lake operators need to provide a complete fishing experience—an experience that is in direct competition with other similar experiences available at no charge. The question pay-lake operators must ask is, can such an experience be provided at a profit?

The concept of "carrying capacity" may be useful in developing a pay-lake marketing program. Carrying capacity refers to the amount of fishing use that a given lake can sustain without substantial reduction in the quality of fishing experience. Carrying capacity must be evaluated in the context of what the fisherman is willing to pay for a given experience in relation to what it costs to provide that experience.

The biological carrying capacity of a lake can be influenced through management practices. Most pay-lake operators rely on periodic stocking to insure an abundance of catchable fish. Pond fertilization and fish feeding can help to insure fish survival. Damage to other physical aspects of the fishing environment can be controlled through site reinforcement—construction of walkways, fencing, tree plantings, etc.

Carrying capacity is also influenced by the number of fishermen who use a lake. As crowding increases, the carrying capacity of

a lake decreases because of a reduction in the quality of fishing experience received. The carrying capacity may be limited more by factors that influence the quality of fishing experience than by biological characteristics of the lake.

The pay-lake operator must try to insure that the carrying capacity of his lake is not exceeded. One real difficulty he faces is that the quality of the product he produces (a day's fishing experience) is reduced as his level of production increases. As more and more fishermen use his lake, the quality of experience goes down. Of course, to combat this situation, the operator can restrict use to the level at which a quality fishing experience will be provided. The real question, however, is whether this level of use is high enough to allow him to make a profit.

The Heiberg experiments are a case in point. Quality fishing is maintained through stocking and controls on the number of fishermen who are allowed to use the ponds at any one time. The maximum number of fishermen allowed on a pond is three per day. Fishermen overwhelmingly are willing to pay for the experience—but the ponds are not operated for profit. Although data have not been compiled, it is reasonable to assume that the cost of providing this exceptionally high quality experience would be much greater than the revenue that would be received if the ponds were operated commercially.

Although this study does provide some insights about the characteristics of potential pay-lake consumers, further market study is needed to determine the influence of accessibility to free public fishing waters on a fisherman's willingness to pay. Furthermore, this study only considered fishermen who were licensed to fish and who came to the Heiberg ponds to fish for trout. Whether these are typical of clientele at commercial pay-lakes remains to be determined.

The information collected in this study is admittedly limited. However, some important questions are raised that pay-lake operators should ask themselves before making additional investments:

- Whom can I serve?
- What kind of fishing experience can I provide that is not readily available at no charge?
- What are the costs involved in providing a fishing experience that is not readily available elsewhere?
- Do I have the resources to provide the quality fishing experience desired?
- What are people willing to pay for the experience?
- Can I make a profit?

There are no easy answers to these questions. The answers must be determined individually for each pay-lake operator. Unless the commercial pay-lake operator tries to answer these questions honestly, the pay-lake fishing market may continue to be as uncertain as it has been in the past.

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by L. R. Auchmoody
and G. W. Wendel

# EFFECT OF CALCIUM CYANAMIDE

## *On Growth and Nutrition Of Planted Yellow-Poplar Seedlings*

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

L. R. AUCHMOODY received his B. S. and M. S. degrees from the State University of New York College of Forestry at Syracuse University. After joining the Northeastern Forest Experiment Station in 1965, he conducted research with Appalachian hardwoods at the Timber and Watershed Laboratory at Parsons, West Virginia. He is currently on the staff at the Station's Forestry Sciences Laboratory at Warren, Pennsylvania.

G. W. WENDEL has been a research forester at the Northeastern Forest Experiment Station, Timber and Watershed Laboratory, Parsons, West Virginia, since 1962. He received his B. S. in Forestry from Iowa State University in June 1951 and his M. F. from Yale University School of Forestry in June 1957. Prior to joining the Northeastern Forest Experiment Station, he worked for 5 years at the Southern Forest Experiment Station and 3 years at the New Jersey Department of Conservation and Economic Development.

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# EFFECT OF CALCIUM CYANAMIDE

## On Growth and Nutrition Of Planted Yellow-Poplar Seedlings


## ABSTRACT

Calcium cyanamide, a nitrogenous fertilizer that also acts as an herbicide, was evaluated over a 3-year period for use in establishing planted yellow-poplar on an old-field site. Results of this study show that first and second year growth of yellow-poplar can be increased by broadcasting $CaCN_2$ around the seedlings. When applied at rates of 400 to 500 pounds of nitrogen per acre, $CaCN_2$ eliminated competing ground cover and supplied nitrogen to the seedlings that promoted vigor and rapid early growth.


CALCIUM CYANAMIDE, ($CaCN_2$), a nitrogen fertilizer that also acts as an herbicide, was evaluated over a 3-year period for use in establishing planted yellow-poplar on an old-field site. Results of this study show that first and second year growth of yellow-poplar can be increased by broadcasting $CaCN_2$ around the seedlings. When applied at rates of 400 to 500 pounds of nitrogen per acre, $CaCN_2$ eliminated competing ground cover and supplied nitrogen to the seedlings that promoted vigor and rapid early growth. Control of competing vegetation was limited mainly to the first season, but a portion of the nitrogen supplied by the cyanamide was available during the second year. As a result of these tests, we recommend this material for yellow-poplar plantings on sites where there is a need to eliminate competing ground cover and where nitrogen supply may be critical.

Fertilization has been recommended as a way of increasing growth of planted hardwood seedlings. However, surface-applied nitrogen fertilizers can stimulate growth of competing vegetation to the extent that seedling growth may often be retarded. Because control of ground cover by plowing and disking is costly and the more common herbicides that might be used for this purpose are generally toxic to hardwoods, there is a need for a nitrogenous fertilizer that does not stimulate competing vegetation.

Calcium cyanamide is a strongly alkaline inorganic compound that contains about 21 percent nitrogen. In the soil, it is hydrolyzed to urea and calcium hydroxide with formation of several unstable intermediate cyanide compounds that are toxic to both seeds and plants. In the presence of ample soil moisture, the toxic substances disappear in 2 to 3 weeks (*2, 5*). In agriculture, it has been used as a pre-plant, pre-emergent, and defoliating herbicide and also as a nitrogenous fertilizer (*4, 5, 6*); but its use in forestry has been limited (*1, 3, 7*). Its usefulness for establishing hardwoods on abandoned agricultural land has not heretofore been investigated.

Between 1969 and 1971, we evaluated the effects of $CaCN_2$ on the control of competing vegetation and upon the growth, survival, and nutrition of yellow-poplar (*Liriodendron tulipifera* L.) seedlings planted on an old field site in north central West Virginia. In these studies, $CaCN_2$ was effective as a nitrogen fertilizer that gave simultaneous control of competing sod and herbaceous vegetation without adverse effects on the seedlings.

## THE STUDY AREA

The study area was located near Leadmine, West Virginia, on a flat bottomland site (fig. 1). Agriculture was discontinued in the area 12 years before the study began. There was a variety of herbaceous and grass species on the site as well as a few widely-scattered white pine, sycamore, and yellow-poplar seedlings.

The soil, Pope loam formed from alluvial deposits weathered from acid gray sandstone and shale of adjoining uplands, is deep and well-drained. The $A_p$ horizon averaged 7 inches deep and had a loamy texture. From 7 to 24 inches, the soil was generally loamy to light silt loam; and between 24 and 60 inches, the texture was predominately fine sand. Fertility of the experimental area was moderately good — probably better than most abandoned agricultural sites in the area (table 1).

Table 1.—*Average soil fertility of the study area*[a]

| Horizon | Sampling depth (inches) | pH | P | K | Ca | Mg |
|---|---|---|---|---|---|---|
| | | | *- - Pounds per acre - -* | | | |
| $A_p$ | 0-7 | 5.8 | 22 | 101 | 2,470 | 63 |
| C | 7-12 | 5.4 | 15 | 86 | 832 | 44 |

[a] pH by glass electrode in 1:1 soil water solution; P colorimetrically after extraction with 0.002 *N* $H_2SO_4$; K, Ca, Mg by atomic absorption after extraction with $NH_4OA_c$. Each value is the average of 10 samples.

Figure 1.—The study area was a topographically uniform old-field site.

# METHODS

Early in 1969, we installed a randomized complete block experiment to test the effects of six levels of $CaCN_2$ on weed control and on yellow-poplar growth and nutrition. Rates of $CaCN_2$ corresponded to 0, 100, 200, 300, 400, and 500 pounds per acre of N.[1] There were five blocks, each containing six 9-tree plots. In each plot, trees were planted in three rows at a spacing of 5 by 5 feet. Plots were separated by 10-foot wide isolation strips.

On March 4, 1969, 1-0 yellow-poplar seedlings selected for their uniformity in height and stem caliber were outplanted. Before the seedlings were planted, their roots were pruned to 8 inches. Their height averaged 10.2 inches, and only seedlings within $\pm$ 2 inches of the average were used.

Pre-weighed amounts of powdered, reagent grade $CaCN_2$ for each of the treatment rates were each mixed with a pound of fine sand to give the material bulk. This mixture was broadcast uniformly over a 3-foot diameter area surrounding each seedling on March 27, 1969. The area of application was controlled by a circular template and protective sleeve placed over the seedling (fig. 2).

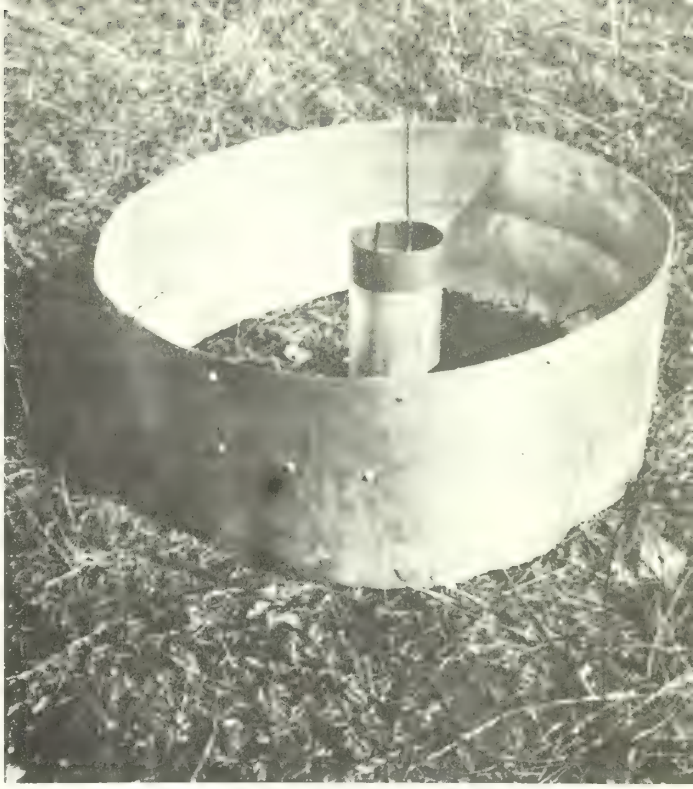


Figure 2.—A circular template and protective sleeve were used to control applications of $CaCN_2$.

The height of the seedlings was recorded at planting time and was remeasured at the end of the 1969 and 1970 growing seasons. Observations on control of competing vegetation were made weekly in 1969 and at 2-week intervals in 1970.

To determine the effect of treatments on the nutrition of the seedlings, samples of mature leaves free from insect and disease damage were collected from each treatment plot in mid-September of 1969 and 1970. Petioles were discarded and blades were dried at 70° C., weighed, and ground to pass a 20-mesh screen. N was determined by the Kjeldahl method. P was measured by the vanadomolybdophosphoric yellow method after wet washing with nitric and perchloric acids, and K, Ca, and Mg by atomic absorption. Nutrients in the leaves were expressed as concentration (percent of leaf dry weight) and as content (milligrams per leaf).

In the spring of 1971 when the seedlings were 3 years old, a second study was superimposed on the original study to determine: (1) whether $CaCN_2$ could be safely applied to established yellow-poplar seedlings; (2) whether protection of the seedlings from the $CaCN_2$ was necessary; and (3) whether time of application was critical.

The new study treatments were applied to 75 seedlings of uniform size in a completely random field design. Treatments were replicated 15 times on single-tree plots, which were 3 feet in diameter. All seedlings except those in the control group received $CaCN_2$ (granular form) at a rate of 500 pounds N per acre. Triple superphosphate at 200 pounds per acre $P_2O_5$ was applied to all seedlings.

Treatment 1 — Application March 15 with seedlings protected

Treatment 2 — Application May 1 with seedlings protected

[1] These rates correspond to 0, 34, 68, 102, 136, and 170 grams of $CaCN_2$ per tree, distributed over an area of 7 square feet.

Treatment 3 — Application June 15 with seedlings not protected

Treatment 4 — Application June 15 with seedlings protected

Treatment 5 — Control

Observations on the control of competing vegetation and on seedling mortality were made periodically throughout the growing season. Seeding height was measured in the dormant season.

# RESULTS

## 1969 Study

### Control of Competing Ground Cover

$CaCn_2$ was very effective in controlling competing ground cover when applied at rates equivalent to 400 or 500 pounds of N per acre (fig. 3). At 300 pounds per acre, it was considerably less effective than at the higher levels; and at rates of 100 or 200 pounds per acre, there was no observable difference between the treated plots and the controls.

At the 400 and 500 pounds per acre rates, much of the ground cover was killed or failed to develop substantially during the first growing season. Both treatments were equally effective, both killed ground cover immediately, and there was no difference in the length of time the vegetation was suppressed. Excellent control of goldenrod, ragweed, yarrow, thistles, joe-pye-weed, cinquefoil, plantain, dock, field basil, ground ivy, red top, timothy, and velvet grass was obtained. (Appendix I).

Dewberry — a ground running member of the blackberry family — was only partially controlled. Although the aerial parts of dewberry were killed, roots in the treated areas had sprouted by the end of the growing season and vines from adjacent untreated areas had encroached upon the plots.

The absence of annual species when $CaCN_2$ was applied at these rates suggests that all

Figure 3.—$CaCN_2$ broadcast at 400-500 pounds per acre N equivalent effectively eliminated most ground cover. Note the sharp boundary between the treated and untreated areas around the seedling.

of the weed seed stored in the surface layer of soil was killed.

At 300 pounds per acre, good control was obtained early in the growing season; but after June, plants and seeds that survived the treatment responded vigorously to reduced competition and abundant N and managed to occupy the site almost fully as the season progressed.

In the beginning of the second growing season, less vegetation was observed only on plots treated at 400 and 500 pounds per acre, but this effect diminished as the season progressed. We feel that the initial reduction in cover was related to a limited seed supply caused by the almost complete kill of vegetation in the preceding year. We also feel that the diminishing effect within the season resulted from rapid development of fall-maturing species, particularly goldenrod, which grew quickly with limited competition and ample N supply.

## Seedling Survival

We did not observe any seedling mortality that could be attributed directly to the $CaCN_2$ treatments. This suggests that the toxic cyanide compounds produced in the soil did not penetrate downward into the rooting zone of the planted seedlings; or if this did occur, concentrations were so diluted that they were not critical to yellow-poplar. The sharp line of lush vegetation outside the treated plots and within the small untreated area surrounding the seedlings (fig. 3) is good evidence that these compounds are immobile and do not diffuse laterally within the soil during their short life span.

Elimination of competing vegetation around the seedlings did not affect first or second year survival. However, where competition was not controlled by $CaCN_2$, seedlings were poor in vigor. Therefore, it is possible that there might be later differences in survival between plots where sod and weeds were eliminated and those where they were not.

## Seedling Height

At the end of the first growing season, seedlings treated at rates of 300, 400, and 500 pounds per acre were significantly taller than untreated seedlings or those fertilized at rates of 100 and 200 pounds per acre (fig. 4). No significant height differences existed within either of these two treatment groups (table 2). Seedlings treated at the three highest rates were also substantially larger in caliper and

Figure 4.—Mean total height of yellow-poplar seedlings at outplanting and at the end of the 1969 and 1970 growing seasons.

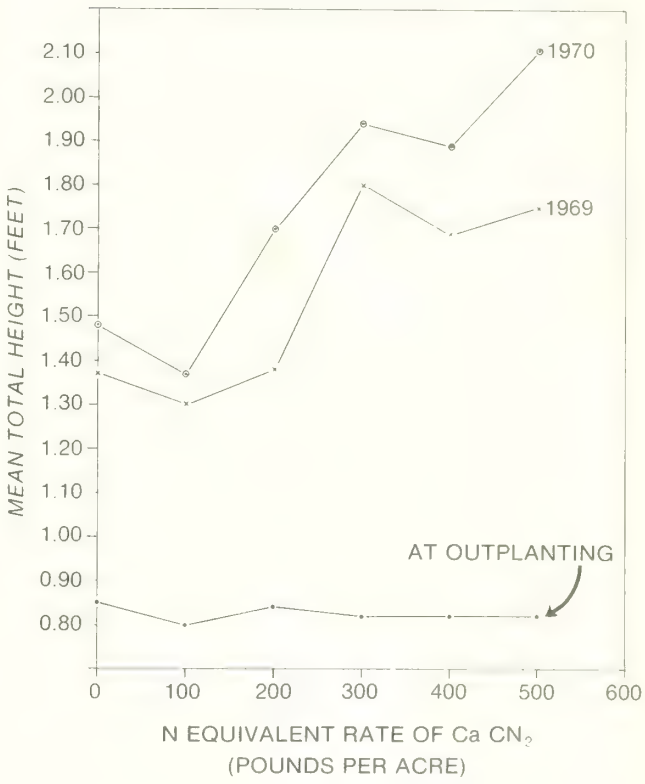



Table 2.—*Mean total heights of yellow-poplar seedlings 1 and 2 years after treatment with varying rates of* $CaCN_2$[a]

| N equivalent rate of $CaCN_2$ (pounds per acre) | Mean height (feet) | |
|---|---|---|
| | *1969* | *1970* |
| 0 | 1.37 a | 1.48 a |
| 100 | 1.30 a | 1.37 a |
| 200 | 1.38 a | 1.70 ab |
| 300 | 1.80 b | 1.94 ab |
| 400 | 1.69 b | 1.89 ab |
| 500 | 1.75 b | 2.11 b |

[a] Values in the same column followed by the same letter are not significantly different (.05 level) as determined by the Student-Newman-Keuls multiple range test.

more vigorous than controls and seedlings treated with 100 and 200 pounds per acre. At the end of the second growing season, only the 500 pounds per acre treatment had significantly taller seedlings than the control (table 2).

The fact that $CaCN_2$ can be used to supply N without stimulating competing cover is of much greater importance than the actual magnitude of response obtained upon this particular site. Because response to any fertilizer is proportional to the degree of nutrient deficiency (if other growth limiting factors are not critical), the increase in growth obtainable from $CaCN_2$ will vary with the N supply of the particular site in question.

Two uncontrollable factors had pronounced effect on the growth on the plots treated with the two heaviest concentrations of $CaCN_2$. First, late spring frosts in both seasons killed back new growth, leaving the seedlings weakened. During the second season, damage was greater on the larger seedlings where growth had been stimulated by the $CaCN_2$.

Second, oviposition damage from the snowy tree cricket (*Oecanthus niveus*) in the new growth of both years tended to be concentrated in the larger seedlings and may have caused a reduction in potential height obtainable from the $CaCN_2$. We feel that these factors have masked to some unknown degree the full benefits on growth that might have otherwise been achieved.

## Seedling Nutrition

*Leaf Weight.* — Average leaf weight increased with increasing rates of $CaCN_2$ above 300 pounds per acre, although the 200 pounds per acre rate also showed a small increase during the second season (fig. 5). At the end of the first season, leaves from seedlings treated at the 300, 400, and 500 pounds per acre rates were significantly heavier than those from seedlings in control and 100 and 200 pounds per acre plots (table 3). In the second season, however, only seedlings treated

Figure 5. — Relationship of average leaf weight to N equivalent rate of $CaCN_2$.

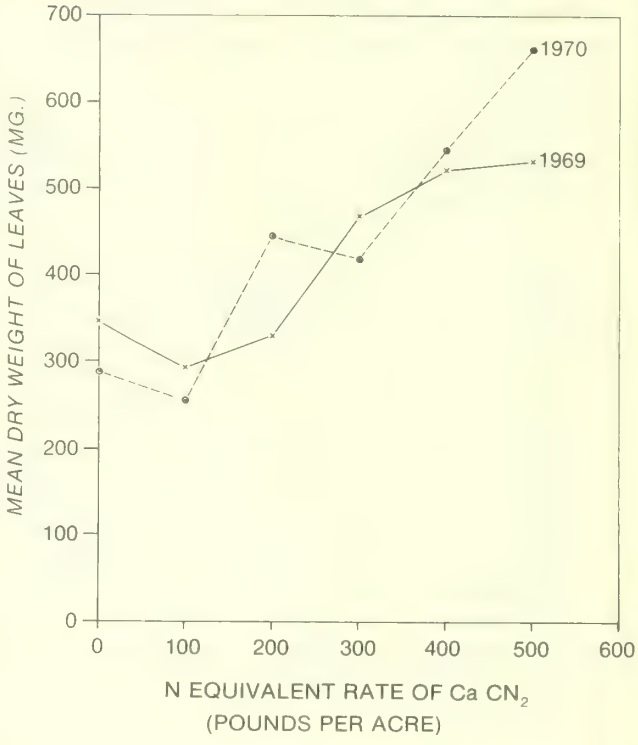
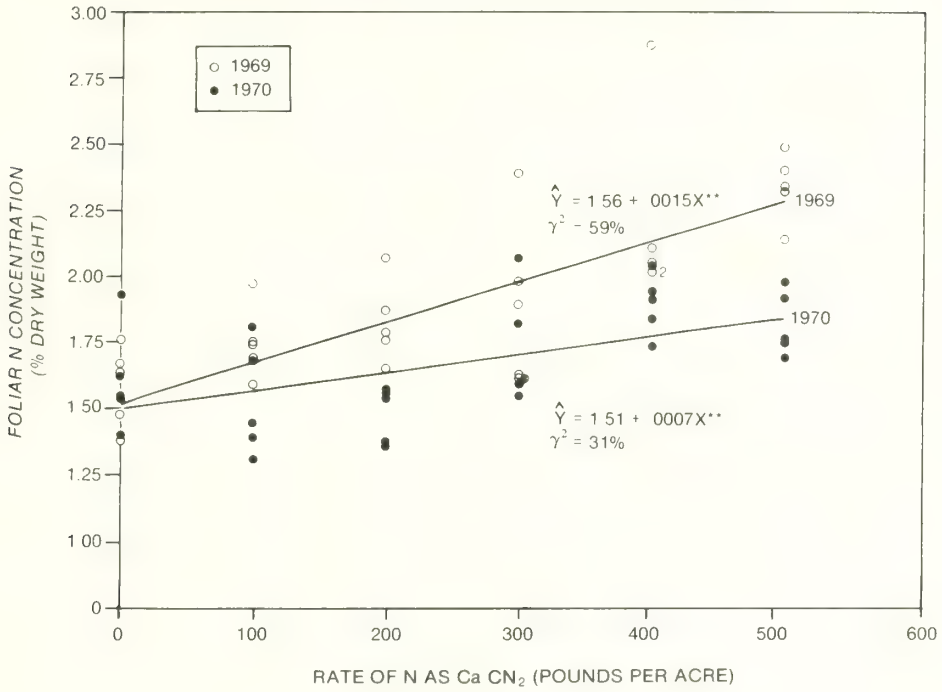



Table 3.—*Concentration and content of N and dry weight of the leaves of yellow-poplar seedlings treated with varying rates of* $CaCN_2$[a]

| N equivalent rate of $CaCN_2$ (pounds per acre) | Dry weight per leaf (milligrams) | | Concentration (percent dry weight) | | Content (milligrams per leaf) | |
|---|---|---|---|---|---|---|
| | *1969* | *1970* | *1969* | *1970* | *1969* | *1970* |
| 0 | 346 a | 289 a | 1.58 a | 1.61 a | 5.40 a | 4.48 a |
| 100 | 293 a | 255 a | 1.75 a | 1.53 a | 5.08 a | 3.85 a |
| 200 | 330 a | 445 abc | 1.83 a | 1.48 a | 5.97 a | 6.68 a |
| 300 | 469 b | 419 ab | 1.90 a | 1.73 a | 8.74 b | 6.37 a |
| 400 | 521 b | 545 bc | 2.22 b | 1.90 b | 11.55 c | 10.33 b |
| 500 | 531 b | 661 c | 2.34 b | 1.82 a | 12.37 c | 12.00 b |

[a] Values in each column followed by the same letter are not significantly different (.05 level) as determined by the Student-Newman-Keuls multiple-range test.

Figure 6.—Relationship between N concentration in yellow-poplar foliage and N equivalent rates of $CaCN_2$ in September of the first and second seasons after treatment.



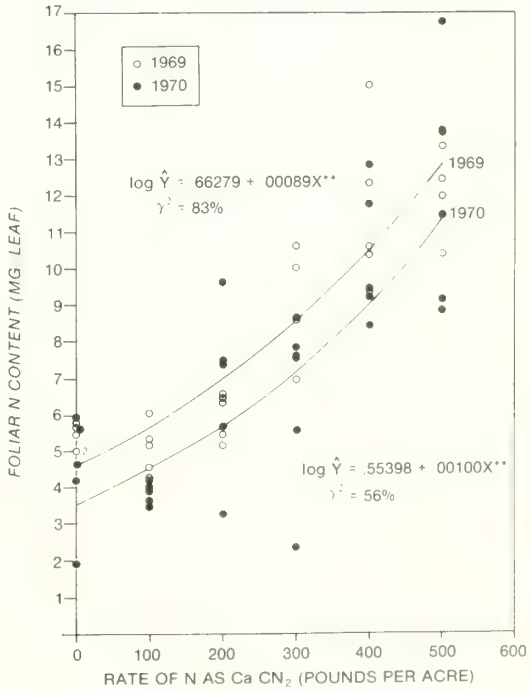

at 400 and 500 pounds per acre had significantly heavier leaves than the controls.

Therefore, leaf weight increased during the first season at rates of 300 pounds per acre or more, but significant carryover of effects into the second season is obtainable only at rates of 400 pounds per acre or more.

*Foliar N.* — Foliar N concentration (percent of dry weight) and actual content of N in the leaves (mg. per leaf) were both significantly and positively ($P < .01$) related to the amount of N applied to the seedlings as $CaCN_2$ (figs. 6 and 7).[2] The relationships were generally linear for concentration and logarithmic for content and were stronger for the first season than they were for the second.

During the first year, the treatments at 400 and 500 pounds per acre significantly increased N concentrations above levels occurring in control seedlings (table 3). At the end

Figure 7.—Relationship between N content in yellow-poplar foliage and N equivalent rates of $CaCN_2$ during September of the first and second seasons after treatment.




[2] This study did not separate effects of fertilization from those stemming from weed control. Therefore an unknown portion of the growth stimulation and nutrient uptake may have resulted from weed control only.

of the second season, seedlings treated at the 400 pounds per acre rate were still significantly higher in foliar N than all other treatments, although seedlings treated at the 500 pounds per acre rate also had about the same concentrations.

The same general pattern was also observed for the actual content of N in the leaves (table 3). In both years, N content was significantly increased by application of $CaCN_2$ corresponding to 400 and 500 pounds per acre, whereas only minor differences occurred between lower rates and controls. There was one exception: in 1969, seedlings treated at the 300 pounds per acre rate had foliar N significantly higher than the controls and lower than the seedlings treated at 400 and 500 pounds per acre.

Table 4.—*Concentration and content of Ca in the leaves of yellow-poplar seedlings treated with varying rates of* $CaCN_2$[a]

| N equivalent rate of $CaCN_2$ (pounds per acre) | Concentration (percent dry weight) | | Content (milligrams per leaf) | |
|---|---|---|---|---|
| | *1969* | *1970* | *1969* | *1970* |
| 0 | 2.65 a | 2.83 a | 9.12 a | 9.60 ab |
| 100 | 2.53 ab | 2.66 ab | 7.37 a | 6.74 b |
| 200 | 2.32 b | 2.66 ab | 7.66 a | 11.85 ab |
| 300 | 2.02 c | 2.77 a | 9.45 a | 10.17 ab |
| 400 | 2.04 c | 2.45 b | 9.79 a | 13.30 ab |
| 500 | 1.78 c | 2.38 b | 9.49 a | 15.63 a |

[a] Values in each column followed by the same letter are not significantly different (.05 level) as determined by the Student-Newman-Keuls mulitple-range test.

Table 5.—*P, K, and Mg concentrations in the foliage of yellow-poplar seedlings treated with varying rates of* $CaCN_2$[a]

| N equivalent rate of $CaCN_2$ (pounds per acre) | Phosphorus | | Potassium | | Magnesium | |
|---|---|---|---|---|---|---|
| | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 |
| | | | *Percent dry weight* | | | |
| 0 | .11 a | .12 a | .66 a | .88 a | .17 a | .30 a |
| 100 | .11 a | .11 a | .56 a | .94 a | .17 a | .27 a |
| 200 | .12 a | .12 a | .61 a | .84 a | .16 a | .29 a |
| 300 | .11 a | .12 a | .55 a | .68 a | .15 a | .22 a |
| 400 | .12 a | .13 a | .60 a | .75 a | .18 a | .27 a |
| 500 | .10 a | .12 a | .59 a | .72 a | .20 a | .27 a |

[a] Values in each column followed by the same letter are not significantly different (.05 level) as determined by the Student-Newman-Keuls multiple-range test.

Table 6.—*Content of P, K, and Mg in the foliage of yellow-poplar seedlings treated with varying rates of* $CaCN_2$[a]

| N equivalent rate of $CaCN_2$ (pounds per acre) | Phosphorus | | Potassium | | Magnesium | |
|---|---|---|---|---|---|---|
| | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 |
| | | | *Milligrams per leaf* | | | |
| 0 | .37 a | .40 a | 2.27 abc | 3.07 a | .60 a | 1.04 ab |
| 100 | .32 a | .29 a | 1.67 a | 2.44 ab | .53 a | .68 a |
| 200 | .39 a | .53 ab | 2.02 ab | 3.66 ab | .54 a | 1.25 ab |
| 300 | .50 b | .43 a | 2.50 bcd | 2.45 ab | .72 ab | .76 a |
| 400 | .58 b | .67 bc | 2.93 cd | 4.01 ab | .94 ab | 1.45 ab |
| 500 | .54 b | .78 c | 3.08 d | 4.72 b | 1.04 b | 1.80 b |

[a] Values in each column followed by the same letter are not significantly different (.05 level) as determined by the Student-Newman-Keuls multiple-range test.

These results indicate that part of the N from $CaCN_2$ applied at rates of 400 and 500 pounds per acre will be retained for use during the second year. At rates below 400 pounds per acre, N will only be available during the first year. Foliar N concentrations of 1.60 percent or less in yellow-poplar seedling leaves indicate N deficiency, and a growth response can be expected from $CaCN_2$ applied at 400 or 500 pounds per acre.

*Foliar Ca.* — Ca concentrations (in percent dry weight) decreased with increasing rates of $CaCN_2$, and the decrease was greater during the first year than during the second (table 4). In the first year, rates of 200, 300, 400, and 500 pounds per acre N equivalent resulted in significantly ($P < .05$) lower foliar Ca concentrations than those that occurred in the controls. But in the second year, only the two heaviest treatments still showed significantly lower concentrations.

In contrast, there were no differences in Ca content (mg./leaf) of the foliage due to treatment until the second growing season. This suggests that lower concentrations were the result of increasingly heavier leaf weights that were uncompensated for by comparable gains in Ca uptake. If further suggests that the Ca contained in the $CaCN_2$ was not available for use by the seedlings until sometime during the second growing season.

*Foliar P, K, and Mg.* — Foliar concentrations of P, K, and Mg were not generally affected by $CaCN_2$ treatments (table 5). In contrast, however, significant gains in content of these nutrients in the foliage were associated with increasing rates of $CaCN_2$ (table 6) and were the direct result of positive changes in leaf dry weight.

## 1971 Study

### Time of Application

Generally, competing vegetation was controlled longer when the $CaCN_2$ was applied during the dormant period (March 15) or early in the season (May 1) as compared to the mid-season (June 15) treatment. Vegetation from the March 15 and May 1 applications was controlled until mid-July, but thereafter the effects diminished. The June 15 treatment, did not completely control the cover; much of the vegetation was merely set back.

There were considerable differences in completeness of kill and length of time vegetation was controlled from the two early $CaCN_2$ applications in this second study compared to those obtained in the first study. Possibly, this was because the $CaCN_2$ used in the 1969 study was the powdered reagent grade $CaCN_2$, whereas in the 1971 study, $CaCN_2$ in granular form was used. The 1969 application killed the weeds completely and lasted longer.

No seedling mortality or serious ill effects were observed from application of 500 pounds per acre, regardless of whether it was broadcast when the seedlings were dormant or actively growing. However, the June 15 treatment did produce very mild orange-colored mottling on the leaves of some seedlings. But this did not result in defoliation or in decrease of seedling vigor.

Seedling growth was equally good and was significantly ($P < .05$) better for all $CaCN_2$ treatments than for control (table 7). Similarly, leaves on the treated seedlings were significantly heavier ($P < .05$) than those on the controls. Leaves on seedlings fertilized on May 15 were significantly heavier than those given any other treatment.

These results show that $CaCN_2$ at 500 pounds per acre (in granular form) can be safely applied to established yellow-poplars

*Table 7.—Mean height growth and mean leaf weight of yellow-poplar seedlings fertilized with $CaCN_2$ (500 pounds per acre N equivalent) at different times during the growing season*[a]

| Treatment (time $CaCN_2$ was applied) | Average height growth | Average leaf weight |
|---|---|---|
| | *Inches* | *Grams* |
| Control | 12.0 a | 0.59 a |
| March 15 | 17.6 b | .81 b |
| May 15 | 20.1 b | 1.12 c |
| June 15 | 17.8 b | .89 b |
| June 15 (No seedling protection) | 18.0 b | .89 b |

[a] Values in each column followed by the same letter are not significantly different (.05 level) as determined by the Student-Newman-Keuls multiple-range test.

without protecting the seedlings from the $CaCN_2$. Application in this locality can be made between mid-March and mid-June without inducing mortality or forfeiting response.

## CONCLUSIONS

1. Yellow-poplar seedlings responded favorably in growth and showed better N nutrition when treated with $CaCN_2$. What is of much greater significance though, is that this compound can be used to supply N without stimulating growth of competing vegetation or harming the planted seedlings.

2. $CaCN_2$ affected seedling nutrition by increasing foliar N concentrations and decreasing Ca concentrations. It had little effect on concentrations of P, K, or Mg. Generally, however, foliar nutrient uptake (milligrams per leaf) increased with increasing levels of $CaCN_2$ due to increases in leaf dry weight. During 1969, Ca uptake was unchanged by the $CaCN_2$ treatments and thus deviated from this general trend.

3. Yellow-poplar seedlings responded in height growth to $CaCN_2$ treatment when foliar N concentrations were about 1.60 percent dry weight, and the best growth was obtained at the 500 pounds per acre N equivalent rate (170 grams of $CaCN_2$ per seedling).

4. $CaCN_2$ broadcast at rates of N equivalent to 400 or 500 pounds per acre during the dormant season controlled competing ground cover around planted yellow-poplar seedlings for the entire first growing season; 300 pounds per acre gave substantially less control, and 100 and 200 pounds per acre rates were not effective.

5. On plots treated with 400 to 500 pounds per acre there was less competition from ground cover during the beginning of the second season, but these effects gradually diminished as the season progressed.

6. $CaCN_2$ broadcast at rates of up to 500 pounds per acre was not toxic to yellow-poplar seedlings. This was true for newly planted stock and for seedlings outplanted for 2 years.

7. $CaCN_2$ in granular form can be broadcast directly around established seedlings without having adverse effects. There is no need to protect the seedlings from the $CaCN_2$ or control the area to which it is applied as long as the proper application rate is maintained.

8. The time of $CaCN_2$ application is not critical. In this study, applications made between March 15 and June 15 all had about the same effect on height growth.

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# APPENDIX I

## COMMON AND SCIENTIFIC NAMES

Yellow-poplar (*Liriodendron tulipifera* L.)
American sycamore (*Platanus occidentalis* L.)
Eastern white pine (*Pinus strobus* L.)
Redtop (*Agrostis alba* L.)
Timothy (*Phleum pratense* L.)
Velvet grass (*Holcus lanatus* L.)
Common yarrow (*Achillea millefolium* L.)
Common ragweed (*Ambrosia artemisiifolia* L.)
Goldenrod (*Solidago ulmifolia* Muhl.)
Joe-pye-weed (*Eupatorium fistulosum* Barratt)
Common thistle (*Cirsium vulgare* (Savi) Tenore)
Old-field-cinquefoil (*Potentilla simplex* Michx)
Upright cinquefoil (*Potentilla recta* L.)
Dewberry (*Rubus* sp.)
Dock (*Rumex* sp.)
Common plantain (*Plantago rugellii* Dane.)
Buckhorn plantain (*Plantago lanceolata* L.)
Field basil (*Satureja vulgaris* (L.) Fritsch)
Ground ivy (*Glechoma hederocea* L.)

# APPENDIX II

## PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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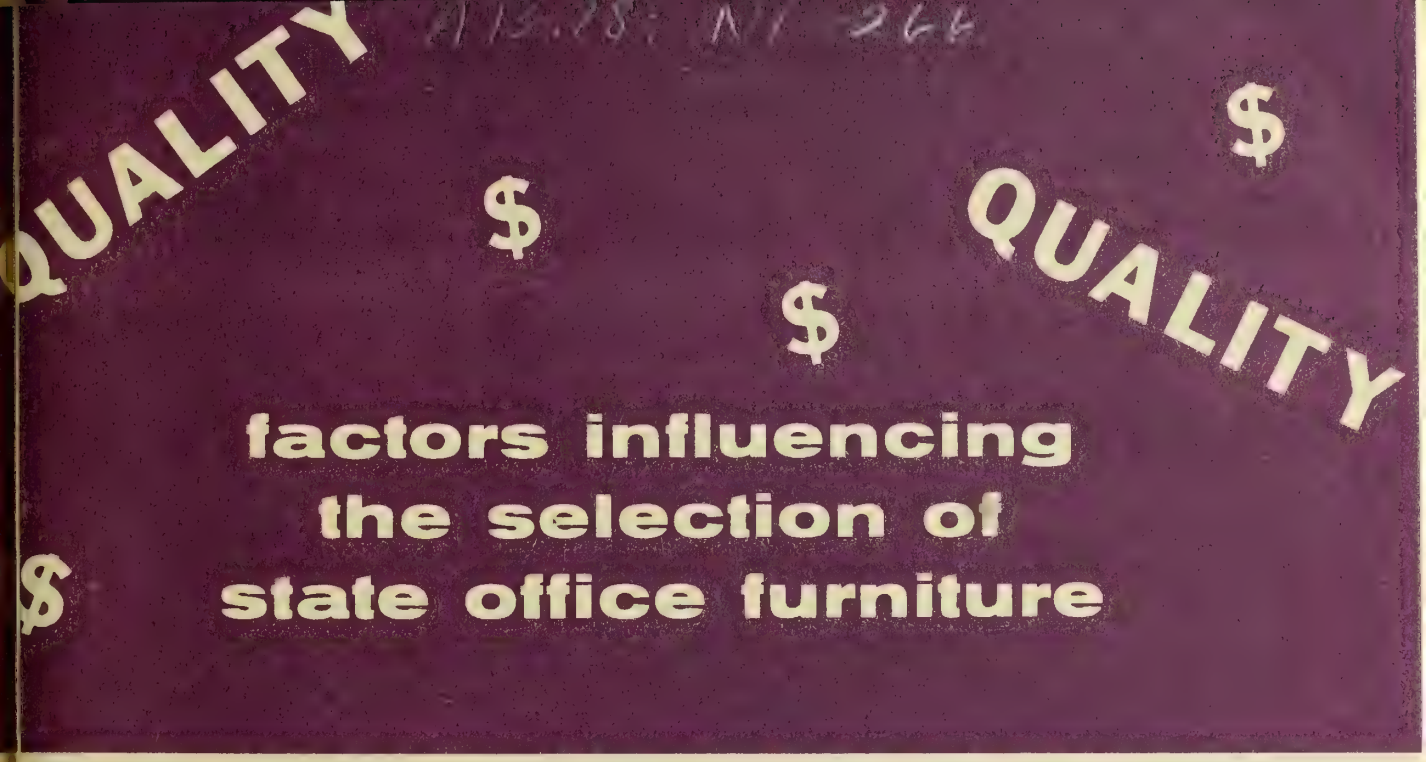


# factors influencing the selection of state office furniture

by r. bruce anderson

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6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Author

R. BRUCE ANDERSON received his bachelor of science degree in forest science from the Pennsylvania State University in 1965 and his master of science degree in wood science from the same institution in 1970. He joined the staff of the Northeastern Forest Experiment Station at the Forest Products Marketing Laboratory, Princeton, West Virginia, in 1969. At the time this report was prepared, he was in charge of furniture research at that laboratory.

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# factors influencing the selection of state office furniture


## ABSTRACT

Evaluation of the factors influencing the selection of office furniture by nine state governments shows that quality and purchase price have the most important influence on the purchase decision. The intended use of the furniture and the purchasing regulations of the states were key factors in the use of wood furniture.


## INTRODUCTION

MANUFACTURERS of wood office furniture have experienced increasing sales over the past decade. The office furniture industry had a total value of shipments of $850 million in 1969 as compared to $490 million in 1964. However, the proportion of wood office furniture to metal office furniture in value of shipments has remained nearly constant.

Unlike the household furniture industry, manufacturers of office furniture do not have an abundance of information defining the factors that influence their customers' purchase decisions. This study, conducted by the U.S. Forest Service Forest Products Marketing Laboratory in Princeton, West Virginia, was the first in a series which attempts to identify the factors that influence the selection of new office furniture. The study's results will help wood office furniture manufacturers to evaluate changes in their production

and marketing procedures that could increase their sales.

## PROCEDURE AND OBJECTIVES

State purchasing officials were interviewed to determine the factors that influence their decisions to purchase particular types of office furniture. The questions in this survey were developed from a pilot survey of office furniture users in the Philadelphia area. Nine state governments[1] were randomly selected from the Northeast region as defined by the United States Department of Commerce. This is the region for which data are available for office furniture in the 1967 Census of Manufacturers.

The objectives of the study were: (1) to determine the relative importance of factors influencing the selection of office furniture; (2) to determine what construction materials (wood, steel, plastic) were most commonly used in the furniture selected; and (3) to determine the comparative advantages of wood versus metal office furniture.

## SURVEY RESULTS

### Market Structure

The survey showed that all of the nine states purchase new wood office furniture; however, the proportion of wood to metal furniture varies widely from state to state. The choice of items is normally made by the operating department or agency which will actually use the furniture. This applies to executive-office furniture as well as general-purpose furniture. The purchasing division acts as a central ordering agency. Funds for the purchase of furniture and equipment are allocated to the separate divisions and agencies within the state, rather than to the purchasing division; but the request for purchase is submitted to the purchasing division for approval and action.

In most cases, the purchasing division maintains a list of approved manufacturers of office furniture and only those firms are invited to bid on the orders. This practice limits the choice of furniture but it also standardizes and simplifies purchasing and tends to insure that the furniture will meet the quality standards of the purchasing division. The purchasing department decides on the grade or quality of furniture to be purchased, decides which manufacturers meet these standards, provides the specifications for the purchase, and finally, invites the approved manufacturers to bid.

The level of administration where the decision to purchase office furniture is made varies between states and depends on the type of furniture purchased. The decision to purchase furniture is usually made separately by either the state purchasing agency or the operating agency; in only one case was the purchase decision made jointly by the two agencies.

The following tabulation shows the administrative level at which the decision to purchase is made, for executive and general purpose office furniture, in the surveyed states.

[1]One purchasing official was interviewed in each of the following states: Connecticut, Delaware, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, and Rhode Island.

| | *Agencies making decision to purchase* | |
|---|---|---|
| *State* | *Executive office furniture* | *General-purpose office furniture* |
| Connecticut | Joint decision (purchasing and operating agency) | Purchasing department |
| Delaware | Operating agency | Purchasing department |
| Maryland | Operating agency | Operating agency |
| Massachusetts | Operating agency | Operating agency |
| New Hampshire | Purchasing department | Purchasing department |
| New Jersey | Operating agency | Purchasing department (blanket) |
| New York | Operating agency | Operating agency |
| Pennsylvania | Operating agency | Operating agency |
| Rhode Island | Operating agency | Operating agency |

Although the operating agencies more frequently initiate the purchase action, that is, make the decision to purchase new office furniture, specifications describing the type of office furniture are usually provided by the purchasing department. The following tabulation illustrates the degree of control exercised by state purchasing departments over the types of office furniture available to the other state agencies.

| *State* | *Specifications provided by:* |
|---|---|
| Connecticut | Acceptable brands list developed within purchasing department. |
| Delaware | Specifications provided by purchasing department. |
| Maryland | Purchase regulations published by Department of Budget and Procurement. |
| Massachusetts | Specifications for wood furniture developed by operating agencies.<br>Specifications for metal furniture developed by purchasing department. |
| New Hampshire | Specifications provided by purchasing department. |
| New Jersey | Specifications provided by purchasing department. |
| New York | Specifications for wood and metal furniture developed out of demands made by operating agencies. |
| Pennsylvania | Purchasing policies published by purchasing department. |
| Rhode Island | Approved bidders list for metal furniture developed by purchasing department. |

Table 1.—*Proportion of wood furniture purchased by selected state governments*

| Furniture type | State | | | | | | | | | Weighted average |
|---|---|---|---|---|---|---|---|---|---|---|
| | CT | DE | MD | MA | NH | NJ | NY | PA | RI | |
| Executive desks | 50 | 80 | 75 | 60 | (*) | 95 | 80 | 100 | 50 | 66 |
| General-purpose desks | 10 | 20 | 75 | 20 | 10 | 10 | 20 | 50 | 10 | 23 |
| Chairs | 10 | 30 | 25 | 20 | 10 | 10 | 20 | 60 | 10 | 20 |
| End tables | (*) | 50 | 100 | 80 | (*) | 50 | 95 | 75 | (*) | 52 |
| Regular tables | (*) | 30 | 80 | 60 | (*) | (*) | 50 | 75 | (*) | 35 |
| Bookcases | (*) | 30 | 50 | 60 | (*) | (*) | 75 | 100 | (*) | 37 |
| Upholstered furniture | (*) | 40 | 50 | 25 | (*) | 40 | 40 | 100 | (*) | 40 |

(*) Less than 10 percent

In Delaware, Maryland, and Pennsylvania, furniture is manufactured in state prisons. In Pennsylvania, use of prison-manufactured furniture is mandatory whenever possible; in Delaware and Maryland it is not mandatory, but prison-produced furniture is significantly lower in price than commercial furniture. This may be one reason why the proportion of wood furniture purchased is high in these states.

### Materials Used in Furniture

Wood and steel are the materials most often used in office furniture purchased by State governments. Table 1 summarizes the proportion of wood furniture of various types purchased by the surveyed states.

Table 1 does not include filing cabinets, although they were included in the survey. Only one state purchased less than 100 percent metal filing cabinets, and that state purchased 98 percent metal and 2 percent wood filing cabinets.

All the furniture not made of wood was metal except upholstered furniture purchased by New York State. In New York, 40 percent of the upholstered furniture purchased was wood, 40 percent was metal, and 20 percent was made of plastics and other synthetic materials.

### Factors Influencing Purchases

State purchasing officials were asked to consider the relative importance of eight factors in the selection of new office furniture. Each factor was considered independently and was rated from *extremely important* to *not important*. The following tabulation shows the order of importance given these factors by the states:

1. Purchase price
2. Appearance
3. Service life
4. Maintenance required
5. Delivery time required
6. Salvage value
7. Salesman contact
8. Advertising

Several purchasing officials added another factor, quality, and rated it higher than or equal to purchase price in importance. Quality was defined as a combination of appearance, service life, maintenance required, and salvage value. Of these four factors, appearance and service life had the most important influence on the purchase decision. Maintenance required and salvage value were of lesser importance in influencing the purchase decision but were included in the overall category of quality.

Although the eight factors were considered independently, it is impossible to completely separate their influence. For example, those state purchasing officials who cited quality as an important factor felt that the purchase price would fall within an acceptable range once quality was established. In these cases, price was considered dependent on quality, and had less influence on the purchase decision.

The appearance of office furniture was important in relation to the setting in which it would be used. This applied to executive as well as general-purpose office furniture. The coordination of colors between the furniture and the general decor of the office was considered, and the style of the furniture was expected to match that of the offices. This was especially true of furniture purchased for new offices.

Service life for most of the office furniture was estimated by the purchasing officials at between 15 and 20 years. In most cases, the expected life of the furniture was considered important in the purchase decision. Several purchasing agents felt that most office furniture is used long after its expected service life has expired.

Maintenance costs were ranked fourth in importance. The purchasing officials preferred furniture which could be repaired or maintained at a reasonable cost. Those states that purchased furniture from state prisons also had furniture repaired by them either at cost or at no cost. Most states contracted with local firms for the repair of furniture. Few states had their own repair facilities.

Delivery time was ranked just below maintenance cost in importance. Of all factors considered, delivery time was the most variable in ranking by individual purchasing agents. In some cases, delivery time was the major factor in the purchasing decision. When large orders of furniture were purchased, delivery time became a very critical factor. In other cases delivery time had no influence in the purchase decision. If manufacturers could not meet the delivery time required in the purchase specifications, they were not listed as approved bidders for office furniture contracts.

Although salvage value was usually included as an element in the broader criterion of quality, it was not considered an important factor in the purchase decision. Most of the purchasing officials felt that the office furniture purchased for state agencies had little or no salvage value at the end of its service life. The explanation given for this was that most office furniture was used for many years longer than its expected service life and the cost of the office furniture was fully depreciated over the 15 to 20 year expected service life.

Sales contacts and advertising were consistently ranked least important. Those purchasing officers who purchased from brokers or wholesalers considered contact with manufacturers' salesmen unnecessary because the wholesalers carried many different lines of both wood and metal furniture. Therefore, those purchasing agents had a wide range of furniture to select from.

The list of approved suppliers limited the number of manufacturers who bid on purchase orders. This also limited the number of salesmen who could or would contact the purchasing officers. Those firms on the bidding list were solicited for bids, and thus did not need to maintain salesmen.

Some office furniture manufacturers advertise with catalogs. This is especially true of

the prisons, which do no other advertising. Purchasing officials need detailed specifications, such as those normally found in manufacturers' catalogs. Advertising through trade journals and similar publications had little influence on the purchase decision, mainly because it did not provide enough detailed information.

### Other Factors

The survey showed that state purchasing officials believe wood and metal furniture are about the same in many respects (table 2). Each purchasing official rated wood and metal office furniture using the following phrases:

| | |
|---|---|
| Modern | Expensive to maintain |
| Expensive to buy | Preferred by employees |
| Durable | Pleasing appearance |
| Easy to clean | Good quality for the price |
| Long service life | Short lead time required |

Out of a total of 90 ratings (one rating for each of the 10 phrases by nine purchasing officials), 48 indicated no difference between wood office furniture and metal office furniture. Eighteen of the ratings favored wood, and 24 of the ratings favored metal.

Six out of nine purchasing officials gave equal rating to wood and metal office furniture on the following qualities: modern, durable, long service life, preferred by employees, and pleasing appearance.

Eight out of nine officials surveyed indicated that they preferred wood for executive office furniture and metal for general-purpose office furniture.

Choice of metal general-purpose office furniture was controlled by the specifications set up by the purchasing departments and could therefore be influenced greatly by the personal preferences of purchasing officials. Choice of wood office furniture, usually executive office furniture, did not depend as much on the specifications but more on the user's preference. The idea that wood is an executive status symbol was pointed out in the responses concerning the officials' personal preferences.

## DISCUSSION AND CONCLUSIONS

The purchasing practices of the surveyed states can influence the proportion of wood as compared with metal office furniture purchased by each state. The use of approved or accepted bidder's lists effectively limits the number of manufacturers who can bid on contracts for office furniture. These lists are established in accordance with a series of rules and regulations governing each state's purchasing policies and reflect the furniture specifications of the purchasing department. Because these specifications most often describe only metal office furniture, the lists of approved bidders are limited to certain manufacturers of metal office furniture.

One factor influencing purchases was the presence of prison industries in three of the states surveyed. These prison industries manufacture wood office furniture and receive preferential treatment. In Maryland and Pennsylvania, the furniture purchased was limited almost exclusively to those types manufactured by the prison industries. As a result, these states purchased a higher percentage of wood office furniture than the other surveyed states.

Table 2.—*Characteristics of wood and metal office furniture as rated by state purchasing officials*

| Characteristic | Wood predominant | Equal rating | Metal predominant |
|---|---|---|---|
| Modern | | X | |
| Expensive to buy | X | | |
| Durable | | X | |
| Easy to clean | | | X |
| Long service life | | X | |
| Expensive to maintain | X | | |
| Preferred by employees | | X | |
| Pleasing appearance | | X | |
| Good quality for the price | | | X |
| Short lead time required | | | X |

Catalogs of wood office furniture produced in the prison industries were available at the purchasing agents' offices. The furniture appeared to be high in quality and yet very low in price when compared to other commercial types of office furniture. Even where buying from the state industry is not mandatory, this price differential could easily be the primary factor influencing the states' purchasing decision.

Availability of wood office furniture that will meet the specifications of the purchasing departments also influenced the states' purchases. Several purchasing officials mentioned uncertainty about the availability of suitable wood office furniture, particularly for general purposes.

Wood office furniture manufacturers are faced with several problems in increasing their share of the state government market for new office furniture. First, they must be listed on approved or accepted bidder's lists maintained by the state purchasing departments. This is especially important for general-purpose furniture, which is most frequently purchased from such lists. Second, they need to develop a general-purpose product line that will provide good quality at a price competitive with metal office furniture. Wood competes favorably with metal in the executive lines. However, general-purpose furniture comprises the bulk of purchases and in this line, metal office furniture is favored primarily because of price. Finally, manufacturers must insure that availability of their product is not limited by excessive delivery times. The ability to assemble pre-finished parts quickly in response to a purchase order has been an advantage enjoyed by metal office furniture manufacturers for some time.

■

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by Michael L. McManus

# The *Role of Behavior* in the dispersal of *Newly Hatched Gypsy Moth Larvae*

JAN

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NORTHEASTERN FOREST EXPERIMENT STATION
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WARREN T. DOOLITTLE, DIRECTOR

## The Author

MICHAEL L. McMANUS obtained his B.S. degree in entomology and M.S. and Ph.D. degrees in forest entomology from Purdue University. He joined the USDA Forest Service in 1966 as a research entomologist. He is now Project Leader of a team conducting research on the population ecology of the gypsy moth at the Northeastern Forest Experiment Station's Forest Insect & Disease Laboratory, in Hamden, Connecticut.

MANUSCRIPT RECEIVED FOR PUBLICATION 7 DECEMBER 1971

# The *Role of Behavior* in the dispersal of *Newly Hatched Gypsy Moth Larvae*


## ABSTRACT

Newly hatched gypsy moth larvae are morphologically and behaviorally adapted for airborne dispersal. The diel periodicity of both hatching and dispersal from the egg mass and photopositive behavior assure that larvae are in optimal position for dispersal when air turbulence is maximal at midday. The rate of larval activity depends upon ambient temperature and relative humidity ($R^2 = 0.77$). The larvae continually trailed silk and did not feed upon reaching the foliage. Rather the larvae appeared predisposed to disperse and were readily dislodged by slight winds.

THE GYPSY MOTH (*Porthetria dispar* L.) has been defoliating hardwoods in New England since its accidental introduction in 1896. It has become endemic in this region, and frequently it reaches locally epidemic levels. The range of this pest has extended steadily southward into central Virginia and westward into central Pennsylvania.

Unlike many lepidopterous pests that disperse actively in the adult stage, the gypsy moth spreads by the inadvertent transport of egg masses on vehicles and various other objects and by windblowing of newly hatched larvae.

The importance of larval dispersal in the spread of this insect was established through experiments conducted at the gypsy moth laboratory at Melrose Highlands, Massachusetts, from 1910 to 1932. It was shown conclusively that the newly hatched larvae could be blown a distance of 21 to 30 miles (*Collins 1917*) and recovered at an altitude of at least 2,000 feet (*Collins 1934*).

Despite the importance of larval spread, little is known about how the larvae respond to external environmental stimuli. This is a report on the importance of behavior in the natural process of dispersal of newly hatched gypsy moth larvae.

Our approach to obtaining this information was to separate the dispersal process into three distinct phases: (1) the period from hatching until the larvae move off the egg mass; (2) the initial distribution of the larvae in the tree crown; and (3) the subsequent moving of larvae from the foliage. Because these larvae are small (3.0 mm.) and difficult to observe on the bark of larger trees, we conducted most of our studies on two small caged trees where we could restrict the movements of the larvae.

# Methods and Procedures

## General

The studies were conducted at Branford, Connecticut, in the summers of 1969 and 1970. The study trees were four black oaks (*Quercus velutina* Lam.), approximately 8 feet tall and 1 to 1½ inches d.b.h. (diameter breast high). Two of the trees were enclosed individually in 9 x 9-foot cages made of monofilament saran (fig. 1), and the other two were left uncaged. The trees were situated in an opening protected on three sides by stands of white pine (*Pinus strobus* L.) and mixed hardwoods.

The larvae we used in these studies came from egg masses collected from a sparse population near Oxford, Connecticut, in January of both years. These were refrigerated at 32°F. until used.

Figure 1.—The tree cage where most of the behavioral studies were conducted.

## Dispersal of Larvae from the Egg Packet

Individual egg masses were enclosed within a saran mesh packet and then stapled to the tree 1 foot above ground. Observations were made on time of hatch, behavior of the larvae while on the packet, and behavior of the larvae as they ascended the tree. Temperatures were recorded continually at the packet surface with a copper-constantan thermocouple, and relative humidity was recorded periodically with a thermistor relative humidity gun. A hygrothermograph was maintained in the immediate area to provide comparative readings of temperature and relative humidity.

During early releases, we noticed that the larvae moved up the tree more rapidly under certain climatic conditions. On overcast days and before rainfall, they were sluggish. But under clear conditions, especially after the recent passage of a high-pressure front, they moved rapidly up the tree.

To quantify this, we determined the rate of ascent of more than 400 larvae from 12 different egg masses by measuring the time required for individuals to travel a 1-foot interval scribed on the bark. Individual larvae were chosen at random as they ascended, and the time of departure and ambient temperature were also recorded.

## Distribution of Larvae in the Tree Crown

Every major branch on the study trees was tagged so that the exact locations of the larvae could be recorded. Total counts were made at 0900, 1200, and 1600 hours daily after larvae were released.

An additional test was designed to evaluate the effect of light on the initial distribution of larvae on the trees after their release. Because of variability in the duration of hatch of any gypsy moth egg mass, a different release procedure was utilized. Two egg masses were incubated together under field conditions. When hatching began, the egg masses were brought inside at room temperature (70°F.) until

about 400 larvae were accumulated. An equal number of larvae were then placed in two small saran trays and stapled to the bases of the caged and uncaged trees. This gave us a known quantity of larvae of approximately the same age (12 to 24 hours).

Three light conditions were tested: (1) a normal exposed tree (uncaged); (2) incident light but no direct overhead light) and (3) a completely darkened tree. The latter two conditions were created by covering the cages in varying degrees with large canvas strips. Total counts were made 1 hour after release and then at the aforementioned intervals.

### Dispersal of Larvae from Foliage

The effect of wind on dispersal was evaluated by releasing equal numbers of larvae (200) on both caged and uncaged trees and then periodically counting the remaining larvae. We were able to estimate the overall effect of the cage in reducing air flow by using a thermistor anemometer. The average maximum velocity both inside and outside the cage was estimated by recording the maximum inclination of the indicator needle at 15-second intervals for running periods of 2 minutes (8 readings). This was repeated at 5-minute intervals for a 30-minute period (total of 48 readings).

The dropping of individual larvae from the foliage was recorded on two occasions by making continuous observations of populations on the caged trees during the day.

## Results

### Hatching and Behavior on the Egg Mass

The period of hatching for an individual egg mass varied from 2 to 5 days. Although newly hatched individuals were recorded on the egg mass throughout the day, most larval emergence occurred early in the morning. Newly hatched larvae can be differentiated from the others because they are buff or tan upon hatching, but turn black in 2 to 4 hours.

After emerging, the larvae spent an indefinite length of time resting on the egg-mass surface before they began moving up the tree. In the spring of 1969, this time ranged from 1 to 49 hours for individual egg masses.

Although environmental conditions during this period obviously affected the larvae, there was no definitive relationship between ambient temperature or relative humidity and the initial movement of larvae off the egg mass. If the egg-mass temperature exceeded approximately 90°F., the larvae usually moved to the back side of the packet, where they were partially shaded. Thermocouple temperatures at the packet surface often exceeded 100°F. in direct sunlight, and many resting larvae withstood these high temperatures with no apparent adverse effects. Larvae normally did not ascend the tree when the ambient temperature exceeded 85°F.

### Dispersal from the Egg Mass

Larvae usually began ascending the tree after 0800 hours. This activity reached a peak between 0900 and 1000 hours, declined at midday, and increased again between 1300 and 1400 hours (fig. 2). A few larvae that hatched in the early morning ascended the tree during the afternoon activity period, but the majority remained on the egg packet until the following morning.

The rate at which individual larvae ascended the tree was determined by the tem-

Figure 2.—The daily pattern of larvae leaving the egg mass and dropping from the foliage, summer 1969-70.

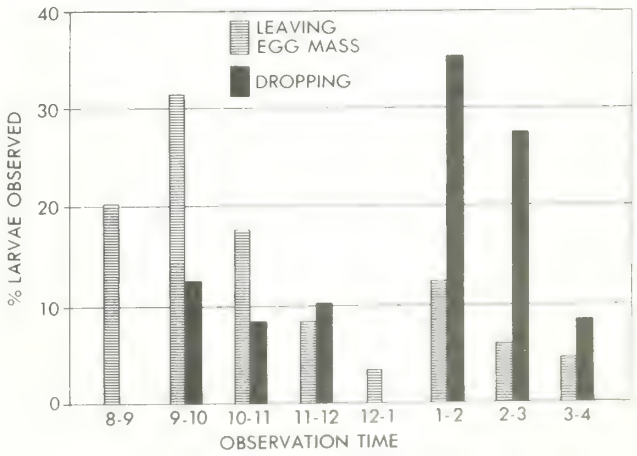


Table 1.—Analyses of variance for the regression of rate of ascent (R) of newly hatched larvae on temperature (T) and relative humidity (RH)

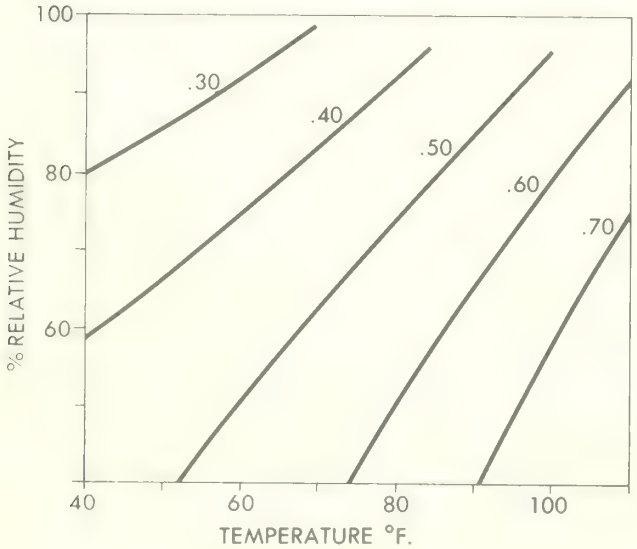
| Source | DF | MS |
|---|---|---|
| T | 1 | 0.01472* |
| RH | 1 | 0.03223** |
| Error | 15 | 0.00307 |

$\hat{R} = 0.4595 + .000036T - .000034RH$

perature and relative humidity at that time. Multiple-regression analysis showed that 77 percent of the variation in rate of ascent was accounted for by these two variables (table 1). The rate of movement was directly related to the combined effect of increasing temperature and decreasing relative humidity (fig. 3).

Although movement of larvae off the egg packet was periodic, larvae moved independently of one another; and no individual leader was evident. Larvae were observed trailing silk, and they tended to follow other silk trails. For example, an adventitious bud that protruded slightly from the side of one tree was repeatedly crossed by individual larvae, although it was somewhat of an obstacle. Accumulated silks could be seen readily at the point of contact both below and above the bud. By forcing a number of larvae to crawl onto a lower branch that they normally avoided, and lay down silk trails in the process, we were able to induce a number of other larvae onto that branch at a later hour of the same day.

Figure 3.—A profile of the rate of ascent of newly hatched larvae (in feet per minute) under variable conditions of temperature and relative humidity.




## Distribution on the Tree

Newly hatched larvae are strongly photopositive and ascend the tree in direct response to overhead light. On sunny days, the larvae

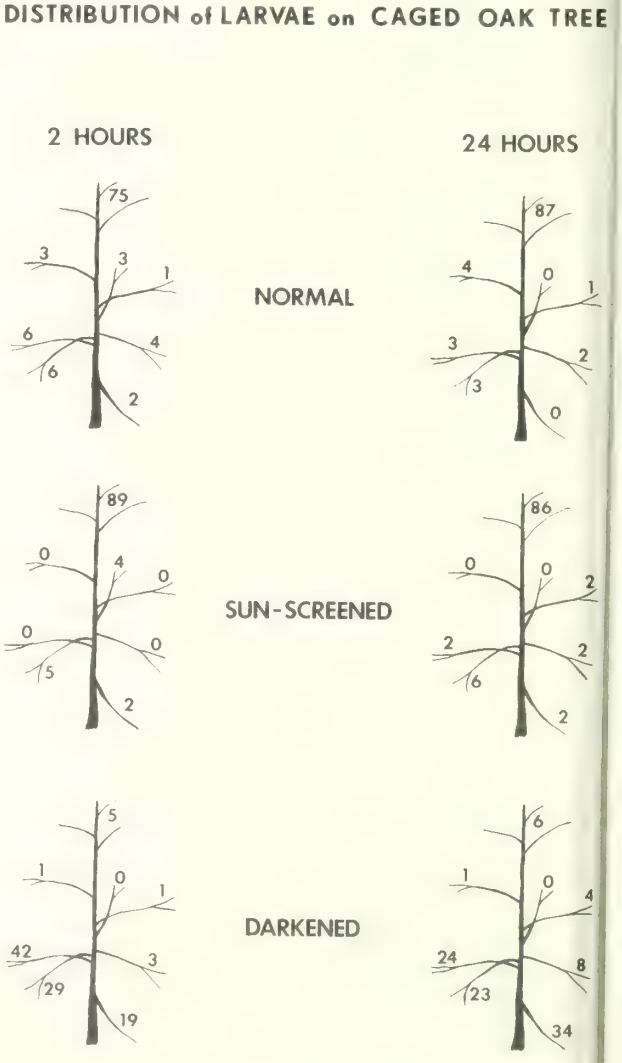



Figure 4.—The percentage distribution of newly hatched larvae after their release on caged oak trees under three conditions of light.

usually moved up that side of the stem that was exposed to the sun, and they accumulated at the highest point of the tree. The only exception to this was in the early morning, when the sun was near the horizon. Larvae initially accumulated at the highest point on the eastern side and then moved to the top branches as the sun moved overhead. On overcast days, they moved directly to the top branches, although their response to dull light was not as strong as their response to bright light (fig. 4).

The percentage distribution was similar on the normal and sun-screened trees at both 2 hours and 24 hours after release. However, on the darkened tree, few individuals moved above the lower tier of branches, and most of the larvae eventually dropped from the branches without feeding.

## Dispersal from the Tree

A large egg mass was allowed to hatch normally under field conditions. Although this egg mass contained 600 to 700 viable eggs, only 140 larva were counted on the tree at any one time because of continual dispersal (fig. 5).

The duration of hatch was 6 days, and second-stage larvae appeared 8 days after emergence began. By this time, the population on the tree had stabilized.

Figure 5.—The change in numbers of larvae on a caged oak after normal hatching of a single egg mass, June 1969.

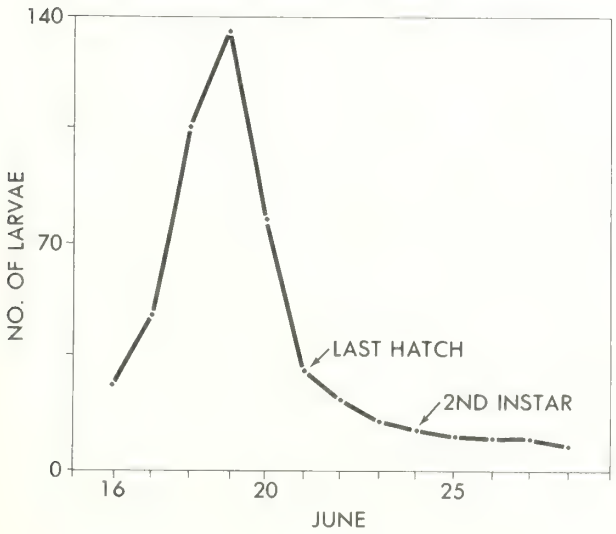


Figure 6.—A group of larvae suspended from an upper branch of a caged oak tree after being dislodged by a slight gust of wind.

When the newly hatched larvae aggregated at the top of the tree, they were continually active on the upper surface of the leaves and twigs and eventually formed a network of silk across the upper branches. They did not feed, although foliage was abundant at all times. A slight gust of wind was sufficient to dislodge them from the foliage and cause them to hang from the tree on silken threads (fig. 6).

Observation of populations on the caged trees revealed that, when winds were less than 2 m.p.h. the larvae dropped readily from the foliage on silken threads. Dropping of the larvae was most evident in the early afternoon between 1300 and 1500 hours (fig. 2); but a light peak occurred between 0900 and 1130 hours, shortly after the peak larval activity period for leaving the egg packet and ascending the tree.

When a larva was suspended on a silken thread, one of three things resulted. (1) The larva extended itself on the thread in response to additional wind until it contacted a surface such as the cage. Often the suspended larva

was blown 360° around the tree and relocated on another branch. (2) The larva extended itself on the thread in response to wind until the thread broke. (3) The larva remained suspended on the silken thread until the wind subsided, then crawled back up the thread onto a leaf or branch. Larvae were seldom observed lowering themselves to the ground.

At a recorded wind velocity of 125 feet per minute (1.2 m.p.h.), a suspended larva was blown out to a position perpendicular to the tree. Any velocity in excess of this was sufficient to cause redistribution of the larvae on the tree. We did not determine the velocity of wind required to dislodge a larva from a leaf surface, or to fracture a silken thread.

Figure 8.—Relationship of the average maximum wind velocity inside and outside the cage on five dates, summer 1969.

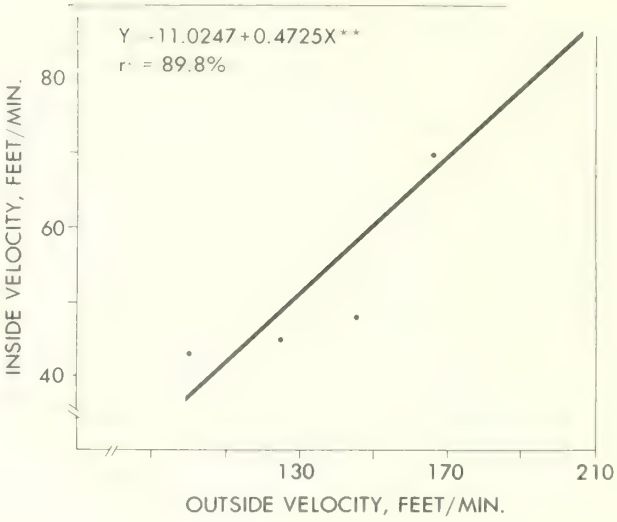
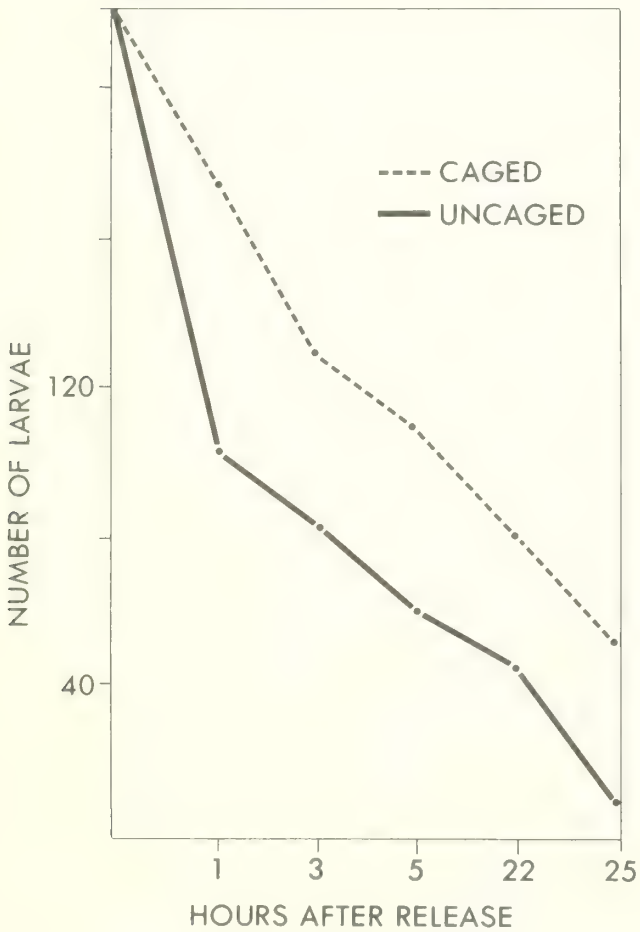



Figure 7.—A comparison of the number of larvae dispersed when 225 newly hatched larvae were released at the base of both caged and uncaged oak trees at 1100 hours, June 1969.




A progressive loss due to dispersal resulted when 225 newly hatched larvae were released at 1100 hours on both caged and uncaged trees (fig. 7). On the uncaged tree, more than 50 percent of the population dispersed within 1 hour of release. On the caged tree, a 15-percent reduction occurred within the same hour.

Releases of equal numbers of larvae on caged and uncaged trees demonstrated the impact of wind on dispersal and the complexity of the dispersal process. The saran cage effectively reduced the average maximum wind velocity by approximately 60 percent (fig. 8). The hourly rate of dispersal of the larvae varied with the time of initial release and the time of day. The dispersal rate 1 hour after release was highest when the larvae were released at 1100 hours (table 2). The difference

Table 2.—Dispersal rate of newly hatched larvae 1 hour after release, July 1969

| Release time (hours) | Average dispersal rate | |
|---|---|---|
| | Caged tree | Uncaged tree |
| 1100 | [1]0.36 | 0.71 |
| 1400 | .24 | .41 |
| 1500 | .37 | .36 |

[1]Each figure represents an average for 2 release dates.

in dispersal rates between caged and uncaged trees was maximal for the 1100 releases and negligible for the 1500 releases. This reduction in dispersal coincided with diminishing air turbulence and reduced larval activity in the late afternoon hours.

The average hourly rates of dispersal were significantly higher the first hour after release than at any other time, (table 3) and are not equally representative for the other time intervals. The hourly rate of dispersal was always higher on the uncaged trees. But in the interval from 1600 to 0900 hours, dispersal was negligible on both the caged and uncaged trees. By 1200 hours of the second day, few larvae were left on the uncaged tree, and the numbers on both trees had stabilized.

Table 3.—Average hourly dispersal rates of newly hatched larvae from caged and uncaged trees within daily time intervals, for four release dates, summer 1969

| Condition | Initial rate of dispersal (1st hour) | Average hourly dispersal rates within time intervals | | | | | |
|---|---|---|---|---|---|---|---|
| | | Day I | | | Day II | | |
| | | 0900-1200 | 1200-1600 | 1600-0900 | 0900-1200 | 1200-1600 | 1600-0900 |
| Caged | 0.33 | — | 0.179 | 0.009 | 0.092 | 0.158 | 0.024 |
| Uncaged | .52 | — | .325 | .029 | .281 | .185 | .021 |

# Discussion

Early studies of the gypsy moth have shown that the newly hatched larvae are easily dispersed by wind. Our observations suggested that, although dispersal may often be passive, larval behavior and activity rhythms are highly adaptive for assuring dispersal in this species.

Upon hatching, gypsy moth larvae are well adapted for windblown dispersal (fig. 9). Burgess *(1913)* reported that the so-called aerostatic hairs on the dorsum of the larvae give them added buoyancy. However, the profuse acuminate lateral hairs are probably more effective in the dispersal process because they effectively increase the lateral surface area of the larvae by eight times.

Because the larvae turn black shortly after hatching, as "black bodies" they readily absorb solar radiation and are active at low ambient temperatures. Although 50°F. was the lowest temperature at which we observed larvae leaving the egg mass and ascending the tree, it is probably not a minimum temperature for this activity.

Leonard *(1970)* observed feeding activity of first-stage larvae at 45°F. Burgess (*1913*) reported from laboratory studies that larvae were not active below 60°F., and that few caterpillars moved about at 65°F. However, his observations were of glass battery jars that were artificially heated from below and therefore did not account for the effect of solar radiation. The internal body temperature of a dark-bodied insect may greatly exceed that recorded at the surface. Gara et al. (*1971*), using blackened bead thermistors to stimulate insects in the field, found that the thermistors heated to 10 to 15°F. above the ambient air temperatures. This would explain why gypsy moth larvae are active at relatively low ambient temperatures.

According to Zanforlin (*1970*), laboratory tests have shown that larvae of Lymantriidae (including the gypsy moth) express both negative geotaxis and positive phototaxis, although the geotaxis is much weaker. This was confirmed in our tests of the effect of light on the distribution of larvae in the tree crown. In the absence of light, the larvae did not ascend the tree and did not feed over a period of days. The strong response to overhead light placed the newly hatched larvae at the tops of the trees, whence they were most rapidly dispersed.

Figure 9.—Dorsal view of a newly hatched gypsy moth larvae, showing profuse acuminate lateral hairs.

It is difficult to equate our observations on silking behavior with those reported earlier by Leonard (*1967*). He concluded from laboratory tests that newly hatched larvae did not trail silk until starved. When this occurred, larvae underwent a phase of increased activity characterized by increased locomotion, irritability, and silking.

Our field studies revealed that newly hatched larvae always trailed silk when ascending the tree, and this was not affected by the length of time spent on the egg packet. The rate of larval ascent and general activity was related to the temperature and relative humidity at that time.

It is possible that, in the spring, all newly hatched larvae attain some level of starvation before they leave the egg mass and ascend the tree. But it would be difficult to ascertain when larvae are starved, because they would be influenced partially by the weather conditions at the time. Forbush and Fernald (*1896*) noted that newly hatched larvae can readily live for 4 days without food under field conditions. And Maksimovic (*1958*) reported that newly hatched larvae can survive up to 8 days without food under variable climatic conditions. Obviously the tolerance of the larvae to starvation is not completely understood.

The behavior of the larvae upon reaching the top branches of the tree also appears to enhance the probability of dispersal. The larvae continually move about and trail silk, but make no attempt to feed. They respond to gusts of wind by arching their bodies, thus increasing their susceptibility to being dislodged. After a period of time, they begin dropping from the foliage on threads of silk. This was more prevalent on the caged trees, where winds were often neglible. If suspended larvae did not contact another surface or become airborne, they immediately began crawling back up the silk to the leaf surface, thus again placing themselves in an opportune position for dispersal.

Foliage quality did not inhibit feeding. When larvae were released in the spring and in mid-July of 1969, succulent foliage was abundant and in July a second flush of growth was produced on the trees. Age of the foliage apparently was not limiting to the newly hatched larvae, because new populations were successfully established on the study trees in late August 1969.

There is a diel periodicity in many aspects of larval activity during the first instar. Hatching, the movement of larvae off the egg mass, and dropping of larvae on silken threads all occur at specific times in the diel cycle. These activity rhythms often have adaptive values.

Hatching began after sunrise and reached a peak between 0600 and 1000 hours. Edwards (*1965*) stated that the hatching of *Hemerocampa* larvae after sunrise allows them to remain active and feeding for some hours just after hatching, instead of remaining inactive for the first 10 to 12 hours, as would be the case if they hatched near sunset. Hatching at this time allows gypsy moth larvae to be exposed immediately to favorable conditions before the peak activity periods during the day.

The main exodus of larvae off the egg packet occurred between 0830 and 1030 hours. This placed the larvae at the tops of the trees before the daily cycle of maximum temperatures and wind. Both the surface wind speed, on which frictional mixing depends, and the intensity of convection have a maximum at midday and a minimum before sunrise (*Geiger 1965*).

The dropping of larvae on silken threads was also rhythmic and was most obvious on the caged trees, where winds were minimal. Although some dropping was evident in the late morning, the peak occurred in the early afternoon (1300 to 1500 hours) when environmental conditions favored dispersal. The loss of larvae from the trees was always highest during this same time.

My observations on the dispersal of larvae from individual trees indicated that two periods of dispersal occurred, the highest rates occurring in the afternoon between 1200 and 1400 hours on the day of release. Although limited to four separate release dates, our results compared favorably with earlier studies by Minott (*1922*) and Leonard (*1971*). They investigated the daily incidence of dispersal by trapping larvae on vertical screens located adjacent to infested woodlands. Minott reported two daily dispersion periods—0900 to 1200 hours and 1400 to 1700 hours, the greatest dispersal occurring during the afternoon period. Leonard found that the peak of larval dispersal occurred in the morning, the highest rate between 0845 and 1000 hours. However, he did recover larvae between 1200 and 1600 hours.

The rhythms exhibited by larvae of the gypsy moth for hatching, dropping, dispersal, and feeding are similar to those discussed by Edwards (*1965*) for the Douglas-fir tussock moth (*Hemerocampa pseudotsugata* McD.). In addition, larvae of both species are nocturnal in the later instars, at least in sparse populations. Adult emergence and flight of males also occur rhythmically in *H. pseudotsugata*, but have not been investigated for the gypsy moth.

Very little is known about qualitative differences among individuals in any gypsy moth egg mass. Leonard (*1970b*) suggested that smaller eggs that occur in *P. dispar* egg masses may be nutritively deficient and yield active larvae that are readily dispersed by wind. My measurements of the rate at which larvae ascended the trees indicated that individual larvae in any sample do move much more rapidly than others. And Leonard's suggestion may well explain these differences.

But the evidence presented here suggests that all newly hatched gypsy moth larvae are predisposed to disperse. However, within any egg mass, a proportionate number of the progeny may be more dispersible than others, or more capable of surviving the stresses created by prolonged or repeated dispersals. The morphology and behavioral responses of the larvae, and the adaptation of events to diel rhythms, indicate that a well-developed system exists to assure dispersal of the larvae from a point source. This may result in the long-range dispersal of gypsy moth larvae under certain optimal conditions, or in their redistribution within a forest stand or local geographical area.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

# FORECASTING GYPSY MOTH EGG-MASS DENSITY

CLEMSON UNIVERSITY
JUL 4

by Robert W. Campbell

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453--145.7 x 18.77 *Porthetria dispar* L.--015.5

## The Author

ROBERT W. CAMPBELL is principal ecologist at the Northeastern Forest Experiment Station's research unit maintained at Syracuse, N.Y., in cooperation with the State University of New York College of Environmental Science and Forestry at Syracuse University. He received his bachelor's degree in forestry from the State University of New York College of Forestry in 1953 and his master's and Ph. D. degrees in forestry from the University of Michigan in 1959 and 1961. He joined the USDA Forest Service's Northeastern Forest Experiment Station in 1961.

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# FORECASTING GYPSY MOTH EGG-MASS DENSITY


## ABSTRACT

Several multiple regression models for gypsy moth egg-mass density were developed from data accumulated in eastern New England between 1911 and 1931. Analysis of these models indicates that: (1) The gypsy moth population system was relatively stable in either the OUTBREAK phase or the INNOCUOUS one; (2) Several naturally occurring processes that could terminate the OUTBREAK phase are represented by the models, but they do not indicate mechanisms sufficient to change the system from the INNOCUOUS phase to the OUTBREAK one. Some of the implications arising from the above conclusions are discussed.


## INTRODUCTION

DATA HAVE BEEN accumulating since about 1890 on various aspects of the gypsy moth/forest system in the northeastern United States. Most of these data, unfortunately, are too limited in scope to be of much potential value to us today.

However, one data base may be an exception: data accumulated between 1911 and 1931 by personnel of the now defunct Melrose Highlands, Massachusetts, Gypsy Moth Laboratory, Bureau of Entomology, USDA, and then stored in a variety of places between 1931 and 1970. Some of these records were lost in a fire that destroyed the Northeastern Forest Experiment Station's Forest Insect and Disease Laboratory at New Haven, Connecticut in 1964.

The relatively massive overall scope of the remaining data was re-discovered in 1970. This is a report on some of our efforts to analyze and interpret these old records. In particular, I have attempted to develop preliminary multiple-regression models from these data for forecasting gypsy moth egg-mass density at the start of "next" year (year n + 1).

## OBJECTIVES

My primary objective was to develop a model from which gypsy moth egg-mass density could be forecast with reasonable accuracy.

A second objective was to use the Melrose data to evaluate as many as possible of the notions about the processes that determine gypsy moth density.

Finally, it was hoped that the models might themselves prove to be useful in expanding our knowledge about the dynamics of this and similar population systems, and that this knowledge might result in new insights about how such population systems should be managed.

## PROCEDURES

### Source Data

The biological data used here were accumulated by personnel of the old Melrose Highlands Gypsy Moth Laboratory. They established 264 plots in 1911 and 1912. Although about 75 of these plots were dropped within 2 years, 122 were maintained through 1921, and 55 were maintained through the fall of 1931. They were scattered along the seaboard of eastern New England from the landward end of Cape Cod to Kennebunk, Maine *(Campbell 1973)*.

Each plot was circular and 100 feet in diameter. Within each plot the species and dominance class of each tree that was at least 3 inches d.b.h. was recorded. Annual records were kept on gypsy moth egg-mass density *(Campbell 1973)*, defoliation per tree, and tree condition. The diameter of each tree was recorded in 1912 and again in 1921.

The weather data we used were extracted from the records of 31 weather-recording stations in the area of interest. The records were obtained from the U.S. Weather Bureau's archives in Asheville, North Carolina.

### Data Processing

The original data set was divided into three decks: the *TREE* deck, the *EGG MASS* deck, and the *WEATHER* deck. The composition of each deck is described below.

The *TREE* deck consisted of 14,266 individual tree records, spanning a maximum of 21 years each. Variables recorded for each tree included plot number, species, diameter class in inches (3-6, 6-9, 9-12, >12), dominance class (dominant, intermediate, suppressed), an annual estimate of tree condition (good, fair, poor, dead), and an annual estimate of defoliation (in 5-percent increments). Tree circumferences were recorded in 1911, and again in 1921 for trees that were still alive and in the plot system.

The *EGG-MASS* deck included plot number, year, egg masses in the plot in years (n — 1), (n), and (n + 1), an index of site soil moisture; the percentage of plots examined in each zone in year (n) that contained (1) more than 500 egg masses per acre, and (2) more than 5,000 egg masses per acre; identification numbers of the closest weather stations and relative distances from these stations to the plot; and approximate elevation of the plot (in feet).

(Dr. David Smith, professor of silviculture at Yale University, who examined the tree records from each plot, was able, in most cases, to place the plot in one of the five site categories. Category 1 represented the driest site, 5 the wettest, and 4 the optimum for tree growth.)

The *WEATHER* deck included the identification number of the weather station, year, monthly precipitation records (in inches), monthly mean spring and summer temperatures, mean minimum winter temperatures, and extreme minimum winter temperature.

The three decks just described were processed to form a *DATA* deck of approximately 2,500 site-years, spanning a 20-year period and representing 190 different stands. (These data will be made available upon request to the author.) Variables in the *DATA* deck were derived as follows:

*Total foliage.*—First, the basal area, in square feet, was calculated for each living stem in each plot. Second, this value was modified according to tree condition, as measured in the previous fall, by using full basal area for trees rated in good condition, 0.75 basal area for trees rated in fair condition, and 0.5 basal area for trees rated in poor condition. Finally,

these adjusted basal areas were summed across all the trees in each plot to derive an index of total foliage, TFOL.

*Overstory components.*—Overstory composition was separated into *ROK*; the percentage of the overstory in the red oak group (red oak and black oak and scarlet oak); *WOK*, the percentage of the overstory in the white oak group (white oak and swamp white oak and chestnut oak); *FCA*, the percentage of the overstory in trees favored by the gypsy moth (all oaks and aspen and gray, paper, and river birch, and larch and willow and apple); *FCC*, the percentage of the overstory in trees known to be unacceptable to the insect under most conditions (ash, black locust, pitch and scots pine, all spruces, and red and white cedar); and *FCB*, the percentage of the overstory in all other species. Each of these components was estimated by deriving the adjusted plot basal area in that component and dividing this by *TFOL*.

*Dominance of favored food trees.*—This variable, *DOM*, is the percentage of the dominant trees on a plot that were favored by the gypsy moth (the FCA trees).

*Stand condition.*—Each living tree in the *TREE* deck was designated as either in good (1.0), fair (2.0), or poor (3.0) condition for each year. These ranks were averaged for each year for all living trees on the plot to yield an estimate of mean stand condition, *COND*.

*Defoliation.*—Mean defoliation levels observed on each plot each year were calculated for trees favored by the gypsy moth (DCA); for food class B trees (DCB), and for the whole stand (DEF). These values were easily calculated, since the original tree deck contained an estimate of the percentage of defoliation for each stem on each plot for each year.

*Precipitation.*—Rainfall on each plot for May and June was estimated from weather-station records. The data from the nearest station were used if the station was within 10 miles of the study plot. If a station was not within this radius, the records from two or three weather stations were interpolated on the basis of distance.

*Temperature.*—Seasonal temperature estimates, mean temperatures during May and June, the mean minimum temperature during the coldest month of the winter between gypsy moth egg-mass counts for years (n) and (n + 1), and the extreme minimum winter temperature, were interpolated from local weather-station data in a manner similar to the precipitation interpolation. However, differences in elevation between the weather stations and the plot were also taken into account. All weather-station temperature data were transformed to their sea-level equivalents, utilizing the relationship of a 5.4°F. decrease in temperature for every 1,000-foot increase in elevation. The distance interpolation was then performed, and the derived temperature was adjusted to the plot elevation.

## The Data Deck

Processed data included an estimate of each of the following variables for every plot in the Melrose system during each year that the plot was examined. Year (n), below, is always the year during which the egg masses designated as MNOW were deposited.

### Independent Variables

| | |
|---|---|
| PM | = Precipitation in May of year (n), in inches |
| PJ | = Precipitation in June of year (n), in inches |
| RM | = Precipitation in May of year (n + 1), in inches |
| RJ | = Precipitation in June of year (n + 1), in inches |
| TMN | = Mean minimum temperature (°F.) during the coldest month between years (n) and (n + 1) |
| TXM | = Absolute minimum temperature (°F.) between years (n) and (n + 1) |
| TM | = Mean temperature (°F.) in May of year (n + 1) |
| TJ | = Mean temperature (°F.) in June of year (n + 1) |
| SSM | = Site soil moisture (driest = 1, . . . , wettest = 5) |
| COND | = Stand condition (good = 1, fair = 2, poor = 3) |

TFOL = An index of total foliage per acre

FCA = Percentage of the total overstory foliage in class A food (all species of oak + gray, paper, and river birch + aspen + larch + willow + apple)

FCC = Percentage of the total overstory foliage in class C food (ash and black locust and pitch and scots pine, all spruces and red and white cedar)

FCB = Percentage of the total overstory foliage in class B food (all species other than FCA and FCC)

ROK = Percentage of the total overstory foliage in the red oak group (red oak and black oak and scarlet oak)

WOK = Percentage of the total overstory foliage in the white oak group (white oak and swamp white oak and chestnut oak)

DOM = Percentage of the dominant trees in the stand that were in food class A (FCA)

DCA(n) = Percentage defoliation of class A trees during year (n)

DCB(n) = Percentage defoliation of class B trees during year (n)

MLSTYR = Egg masses per acre in the fall of year (n − 1). (One egg mass was added to observed per-acre egg-mass density in each plot because in some cases observed egg-mass density was zero.)

MNOW = Egg masses per acre in the fall of year (n)

ZDL = Percentage of acres examined in a zone during year (n) that contained more than 500 egg masses per acre

ZDH = Percentage of acres examined in a zone during year (n) that contained more than 5,000 egg masses per acre

TREND = $\frac{\text{MNOW}}{\text{MLSTYR}}$

DEF(n + 1) = Percentage defoliation of whole stand during year (n + 1)

**Dependent Variable**

MNXTYR = Egg masses per acre in the fall of year (n + 1). (One egg mass was added to observed per acre egg-mass density in each plot because in some cases observed egg mass was zero.)

## Analytical Format

In analyzing these data, I sought primarily to produce a model useful for *predicting* egg-mass density. Although the model may also prove to be useful in *understanding* something of the processes through which particular density levels are determined, this was not intended as its primary function. This distinction, which is discussed elsewhere in more detail *(Campbell 1971)*, has an important bearing on the way the data were anlayzed here.

First, the data were stratified according to overstory composition into *OAK* stands, where more than one-half the total overstory foliage was oak (ROK + WOK), and *POOR FOOD* stands, where less than one-half the total overstory foliage was in tree species favored as food by gypsy moth larvae (FCA). (A third stratum, containing stands where more than one-half of the overstory foliage was in food class A, but where less than one-half was in oak, was set aside for later analysis.)

Second, a variety of multiple regression models, having the general form $Y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n$, were tested, provisions being made for both non-linear relationships and interactions among the independent variables, after both MNXTYR and MNOW were transformed to their natural logarithms, ln(MNXTYR) and ln(MNOW). In particular, a large number of the unpublished notes and manuscripts (on file at the Forest Insect and Disease Laboratory, USDA Forest Service, Hamden, Connecticut) that reflect the thoughts of some of the Melrose Laboratory personnel on the implications of their data with respect to gypsy moth density proved to be helpful in formulating these models.

# RESULTS

The best model for *POOR FOOD* stands, using the criteria of least squares, is presented in table 1. Since 66 percent of the variation in ln (MNXTYR) was associated with variation in the independent variables, this model may prove to be useful for forecasting egg-mass density in such stands. It should be tested as soon as possible.

Two models are presented for ln (MNXTYR) in *OAK* stands (tables 2 and 3). The former model, which includes only independent variables that could be observed by March 1 of year (n + 1), accounted for 67 percent of the variation in ln (MNXTYR) (table 2). The latter model, which incorporates two independent variables that could not be observed directly before a control decision would have to be made, accounted for 74 percent of the variation in ln (MNXTYR) (table 3). Both models should be tested as soon as possible.

Since the models are additive, the contribution of each term to ln (MNXTYR) can be examined separately, and the expected value of egg-mass density itself can be determined by simply transforming ln (MNXTYR) back to MNXTYR. This procedure was followed in developing figures 1 to 18, wherein each independent variable in model three (table 3) is examined with respect to egg-mass density in the fall of year (n + 1). (Since these figures were all derived by using the mean value of each independent variable that was not otherwise specified, these mean values are shown in the appendix.)

### Site Density and Zone Density

Changes in gypsy moth density within any specific place were known to be a function of zone density, the general density level of the population system within a larger, spatially defined area, since previous studies had indicated that the Melrose system could be separated into two phases, INNOCUOUS and OUTBREAK, with respect to expected trends in egg-mass density on the basis of zone density *(Campbell 1973)*.

Two measures of zone density were used: ZDL or low zone density, the percentage of the acres examined within any given zone in the fall of year (n) that contained more than 500 egg masses per acre; and ZDH or high zone density, the percentage of the acres examined in the zone that contained more than

Table 1.—Analysis of variance in egg-mass density per acre in year (n + 1) (ln MNXTYR) as a function of the specified independent variables. POOR FOOD stands; N = 1,037.

| Source of Variation | DF | MS | F |
|---|---|---|---|
| Regression | 14 | 306.2 | 143 |
| Residual error | 1,022 | 2.1 | — |

Intercept = 2.296

| Variable | Regression Coefficient | Standard error of coefficient | t ratio on 1,022 d.f. |
|---|---|---|---|
| $(ZDL)^2$ | 0.00098629 | 0.00013893 | 7.1** |
| $(ZDL)^3$ | —.00000734 | .00000156 | —4.7** |
| (ZDH) | .28347040 | .05245863 | 5.4** |
| (ZDL) · (ZDH) | —.00725148 | .00161175 | —4.5** |
| $(ZDL)^2$ · (ZDH) | .00004506 | .00001197 | 3.8** |
| $(PM)^2$ | —.14280650 | .03367144 | —4.2** |
| $(PM)^3$ | .01426990 | .00417453 | 3.4** |
| (PM) · (lnMNOW) | .04810875 | .01454296 | 3.3** |
| $(TMN)^2$ | —.00307362 | .00071851 | —4.3** |
| (TMN) · (lnMNOW) | .01113269 | .00301615 | 3.7** |
| (FCB) · (lnMNOW) | .00425318 | .00125357 | 3.4** |
| $(FCB)^3$ · (lnMNOW) | —.00003111 | .00001086 | —2.9** |
| (TFOL) · (DOM) | .00016320 | .00005453 | 3.0** |
| (TFOL) · $(DOM)^2$ | —.00000162 | .00000080 | —2.0* |

*Significant at 0.05 probability level.
**Significant at 0.01 probability level.
$R^2 = 0.66$.

Table 2.—Analysis of variance in egg-mass density per acre in year (n + 1) (lnMNXTYR) as a function of the specified independent variables. OAK stands; N = 555.

| Source of Variation | DF | MS | F |
|---|---|---|---|
| Regression | 17 | 148.2 | 72 |
| Residual error | 537 | 2.1 | — |

Intercept = 3.409

| Variable | Regression coefficient | Standard error of coefficient | t ratio on 537 d.f. |
|---|---|---|---|
| $(ZDL)^2$ | 0.00144493 | 0.00022818 | 6.3** |
| $(ZDL)^3$ | —.00001176 | .00000259 | —4.5** |
| (ZDL) · (ZDH) | .00539065 | .00148093 | 3.8** |
| $(ZDL)^2$ · (ZDH) | —.00013696 | .00003969 | —3.5** |
| $(ZDL)^3$ · (ZDH) | .00000085 | .00000028 | 3.1** |
| (TREND) · (lnMNOW) | —.03299060 | .01029203 | —3.2** |
| (TREND) · $(lnMNOW)^2$ | .01071147 | .00291401 | 3.7** |
| (TREND) · $(lnMNOW)^3$ | —.00083713 | .00021198 | —3.9** |
| $(PM)^2$ | —.06813522 | .02896474 | —2.4** |
| $(PM)^3$ | —.00775066 | .00426570 | 1.8[a] |
| $(TMN)^2$ | —.00522347 | .00074895 | —7.0** |
| (TMN) · (lnMNOW) | .02198500 | .00274274 | 8.0** |
| (WOK) · (lnMNOW) | —.00626965 | .00183840 | —3.4** |
| (WOK) · $(lnMNOW)^2$ | .00073208 | .00023822 | 3.1** |
| (FCA) · (lnMNOW) | .00163645 | .00056021 | 2.9** |
| $(FCC)^2$ · (ZDL) | —.00003635 | .00001861 | —2.0* |
| (DCA (n) ) · (lnMNOW) | —.00156839 | .00033867 | —4.6** |

*Significant at 0.05 probability level.
**Significant at 0.01 probability level.
[a]Significant at 0.10 probability level.
$R^2 = 0.67$.

Table 3.—Analysis of variance in egg-mass density per acre in year (n + 1) (lnMNXTYR) as a function of the specified independent variables, including precipitation in June of year (n + 1) and defoliation in year (n + 1). OAK stands; N = 533.

| Source of variation | DF | MS | F |
|---|---|---|---|
| Regression | 22 | 112.1 | 65 |
| Residual error | 510 | 1.7 | — |

Intercept = 3.53

| Variable | Regression coefficient | Standard error of coefficient | t ratio on 510 d.f. |
|---|---|---|---|
| $(ZDL)^2$ | 0.00203155 | 0.00024235 | 8.4** |
| $(ZDL)^3$ | —.00001862 | .00000280 | —6.6** |
| (ZDL) · (ZDH) | .00502920 | .00130149 | 3.9** |
| $(ZDL)^2$ · (ZDH) | —.00013631 | .00003681 | —3.7** |
| $(ZDL)^3$ · (ZDH) | .00000088 | .00000026 | 3.4** |
| (TREND) · (lnMNOW) | .11396300 | .04357555 | 2.6** |
| (TREND) · $(lnMNOW)^2$ | —.26747010 | .01086141 | —2.5* |
| (TREND) · $(lnMNOW)^3$ | .00148031 | .00060085 | 2.2* |
| $(PM)^2$ | —.06666974 | .02820550 | —2.4* |
| $(PM)^3$ | .00879564 | .00413062 | 2.1* |
| (RJ) · (ZDL) | —.00961119 | .00211648 | —4.5** |
| (RJ) · $(ZDL)^2$ | .00009795 | .00002789 | 3.5** |
| $(TMN)^2$ | —.00522493 | .00069087 | —7.6** |
| (TMN) · (lnMNOW) | .02789139 | .00247935 | 11.2** |
| (WOK) · (lnMNOW) | —.00573563 | .00178512 | —3.2** |
| (WOK) · $(lnMNOW)^2$ | .00079620 | .00022758 | 3.5** |
| (WOK) · (ROK) | —.00053924 | .00022538 | —2.4* |
| (WOK) · $(ROK)^2$ | .00000924 | .00000391 | 2.4* |
| $(FCC)^2$ · (ZDL) | —.00003377 | .00001700 | —2.0* |
| (DCA (n) ) · (lnMNOW) | —.00184766 | .00032763 | —5.6** |
| (DEF (n+1)) · (lnMNOW) | .00926943 | .00114017 | 8.1** |
| (DEF (n+1) )²· (lnMNOW) | —.00011429 | .00001395 | —8.2** |

*Significant at 0.05 probability level.
**Significant at 0.01 probability level.
$R^2 = 0.74$.

5,000 egg masses per acre. Since high zone density was usually zero until low zone density reached 40 percent, changes in egg-mass density are shown in figure 1 for low zone densities ranging from zero to 40 percent, with high zone density set at zero. Both low zone density and high zone density were allowed to vary in figure 2, for the egg-mass density values shown.

Density in the fall of year (n + 1) is shown in figure 1 for three values of current egg-mass density (MNOW). These values (50, 250, and 500 egg masses per acre) were also held constant at these same values in the fall of year (n — 1) (MLSTYR). About 50 egg masses per acre could be expected to decrease to about 40 egg masses per acre when low density was less than 20 percent, but it might increase to about 150 egg masses per acre when low zone density reached 40 percent. Five hundred egg masses per acre, on the other hand, could be expected to decrease to about 125 egg masses per acre when low zone density was less than 20 percent, and would still decrease slightly (to about 450 egg masses per acre) even when low zone density reached 40 percent. All densities could also be expected to be slightly lower in year (n + 1) when low zone density was 10 percent than when it was zero.

The results (fig. 1) indicate that isolated high-density populations could be expected to return to low, innocuous densities within a year or so, and that sparse populations could be expected to remain stable at low density levels as long as their neighboring populations were at low levels.

Five levels for high zone density (0, 10, 20, 30 and 40 percent) are shown (fig. 2) for all

Figure 1.—Relationships between egg-mass density per acre in the fall of year (n + 1) (MNXTYR), egg mass densities per acre in the fall of years (n — 1) and (n) (MLSTYR and MNOW), and the percentage of the plots in the zone containing more than 500 egg masses per acre in the fall of year (n). All other independent variables have been held constant at their mean values.

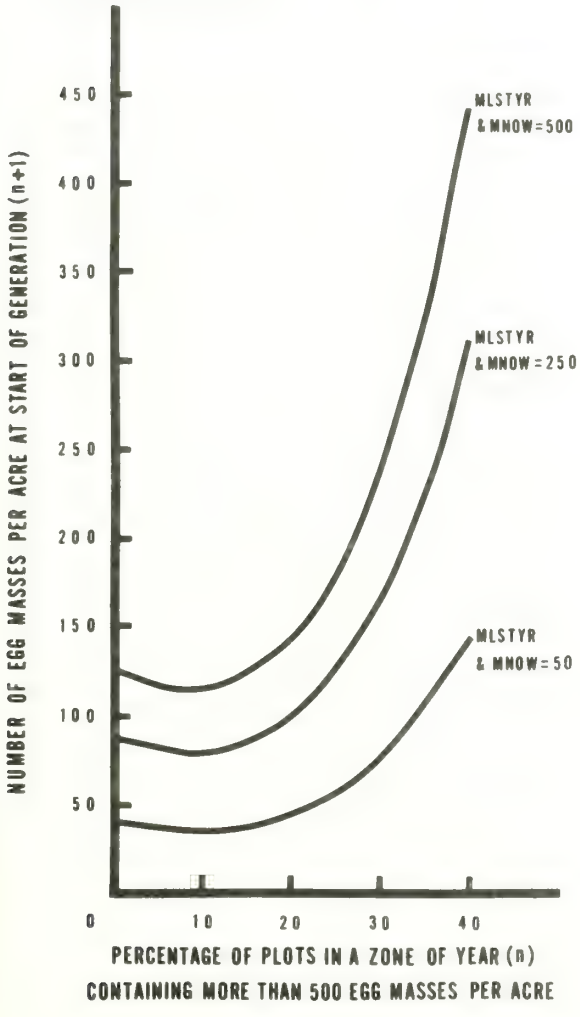
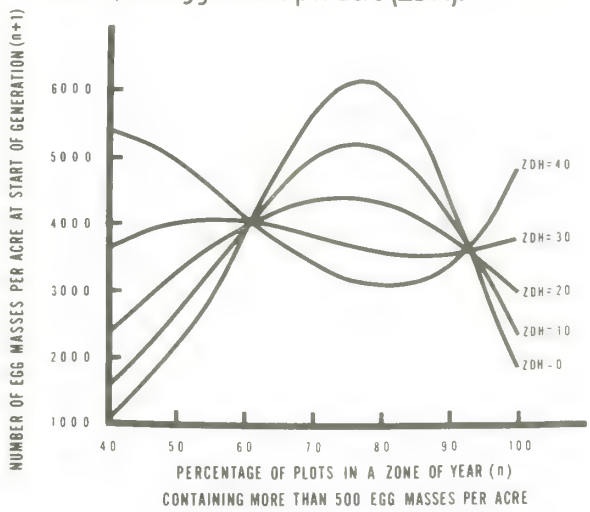



Figure 2.—Relationships between egg-mass density per acre in the fall of year (n + 1), and the percentages of the acres in the zone in the fall of year (n) containing: (a) more than 500 egg masses per acre (ZDL), and (b) more than 5,000 egg masses per acre (ZDH).

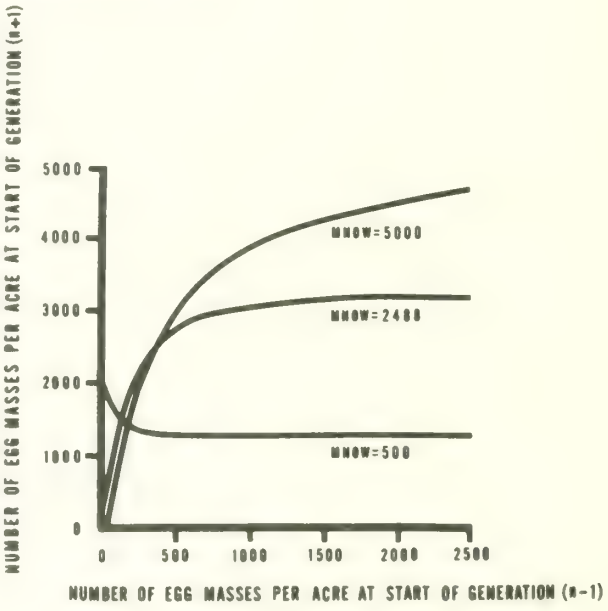


values of low zone density from 40 to 100 percent. In this case, both prior egg-mass density (MLSTYR) and current egg-mass density (MNOW) were set at their mean values, 2,705 and 2,488 egg masses per acre.

Relationships between low zone density (ZDL), high zone density (ZDH), and egg-mass density per acre within any specific place in the fall of year (n + 1) (MNXTYR) reversed twice within the range of low zone densities shown. When ZDL was near 40 percent or 100 percent, a much higher density could be expected in any given place when ZDH was high than when it was low, but when ZDL was between 65 and 90 percent, higher densities could be expected in any given place when ZDH was low than when it was high.

These results suggest that this system contained internal mechanisms for maintaining itself within the OUTBREAK phase for an indefinitely long period of time; that internal mechanisms existed for constraining this phase so that it neither collapsed nor increased without bounds.

Figure 3.—Relationships between egg-mass density per acre in the fall of year (n + 1), and egg-mass densities per acre in the fall of years (n — 1) and (n) (MLSTYR and MNOW). Outbreak conditions.




## Site Density Under Outbreak Conditions

Figures 3 to 10 represent expected values of gypsy moth egg-mass density under OUTBREAK conditions. Both low zone density and high zone density were set at their mean values (53 percent and 14 percent) in these figures.

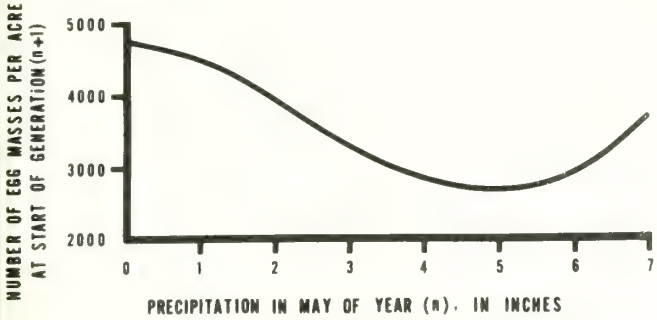
*Egg-mass densities (MLSTYR) and (MNOW).*—Egg-mass density per acre in the fall of year (n + 1) (MNXTYR) is shown in fig. 3 as a function of current density (MNOW) and density in the fall of year (n + 1) (MLSTYR).

Individual populations that had been stable at about 5,000 egg masses per acre for 2 years running tended to maintain high densities for a third year, while populations that had increased dramatically from a lower density in year (n — 1) to 5,000 egg masses per acre in year (n) tended to decrease. No plausible mechanisms can be suggested at this time through which the first of these results might have been determined, but one mechanism that might have been involved in determining the second sort of outcome is suggested below.

Suppose current density had been reached through a dramatic increase from year (n — 1) to (n). Density continued to increase greatly from year (n) to (n — 1) when year (n) density was 500 egg masses per acre, but greatly from year (n) to (n + 1) when year year (n) density was 5,000. Both populations may have temporarily expanded beyond the ability of their natural enemies to prevent further increase, but the former population may have been more likely than the latter to reach a density level where food exhaustion and physiological stress, leading to population collapse, were likely to occur.

*Precipitation in May of year (n) (PM).*—The relationship between precipitation in May of year (n) and gypsy moth egg mass density in the fall of year (n + 1) indicates that density decreased as precipitation in May of year (n) increased from zero to about 5 inches, but that density tended to increase in year (n + 1) as precipitation in this month increased above 5 inches (fig. 4). These re-

Figure 4.—Relationship between egg-mass density per acre in the fall of year (n + 1) and precipitation in May of year (n) (PM). Outbreak conditions.




sults may indicate that disease incidence increased and reduced population density in year (n + 1) as a function of increasingly high precipitation in May of year (n), but they also suggest that precipitation levels above about 5 inches in May of year (n) may reflect the operation of a hitherto unsuspected mechanism, which was influenced in some way by exceptionally high precipitation levels in May of year (n), through which the physiological state of the insect is altered in year (n + 1).

*Precipitation in June of year (n + 1) (RJ.)* —Relationships between ZDL, the percentage of the acres examined in a zone that contained more than 500 egg masses per acre in the fall of year (n), RJ, the number of inches of rainfall in June of year (n + 1), and MNXTYR, egg-mass density per acre in the fall of year (n + 1), are shown in figure 5. June precipitation in year (n + 1) bore a particularly close relationship to subsequent egg-mass density *(Campbell 1967a)*. This close statistical relationship probably reflects both the underlying relationship between precipitation and disease incidence among instar IV to VI larvae, and the importance of variation in the survival rate during this particular age interval to variation in egg density in the fall of the year *(Campbell 1967a)*.

The results (fig. 5) support the notion that exceptionally heavy precipitation levels in June of year (n + 1), if they are sufficiently widespread, may indicate the abrupt collapse of the OUTBREAK phase.

*Mean minimum winter temperature (TMN).*—Gypsy moth eggs cannot survive at temperatures below about —20°F., which is probably reflected (fig. 6) in relationships between the mean minimum temperature during the coldest month between year (n) and (n + 1) (TMN), current egg-mass density (MNOW), and egg-mass density in the fall of year (n + 1) (MNXTYR). Egg-mass density in year (n + 1) was usually reduced to an innocuous level when the mean minimum winter temperature was about zero °F., another naturally occurring mechanism through which the OUTBREAK phase could be reduced to the INNOCUOUS one.

Egg-mass density in year (n + 1) was somewhat lower when the mean minimum temperature was exceptionally high than when it was close to its mean value (14°F.), and the

Figure 5.—Relationships between egg-mass density per acre in the fall of year (n + 1), precipitation in June of year (n + 1) (RJ), and percentage of the acres in the zone in the fall of year (n) containing more than 500 egg masses per acre (ZDL). Outbreak conditions.

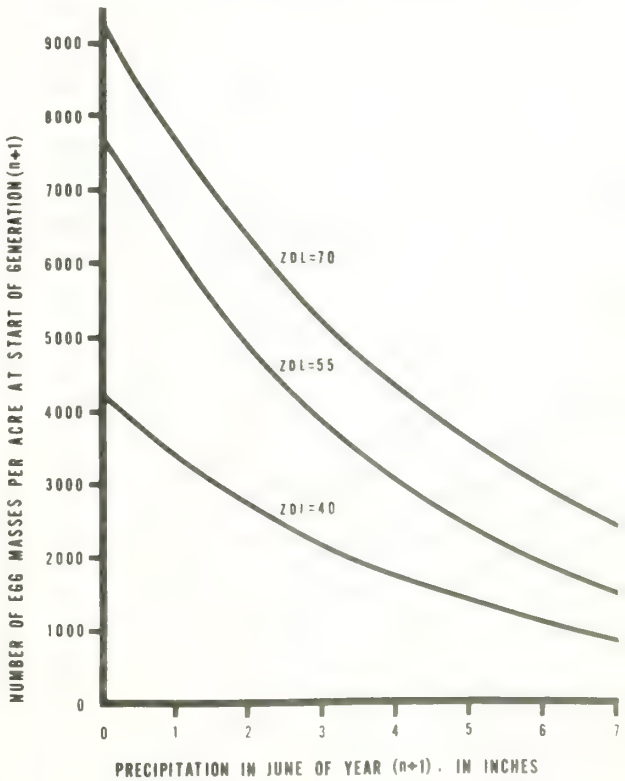
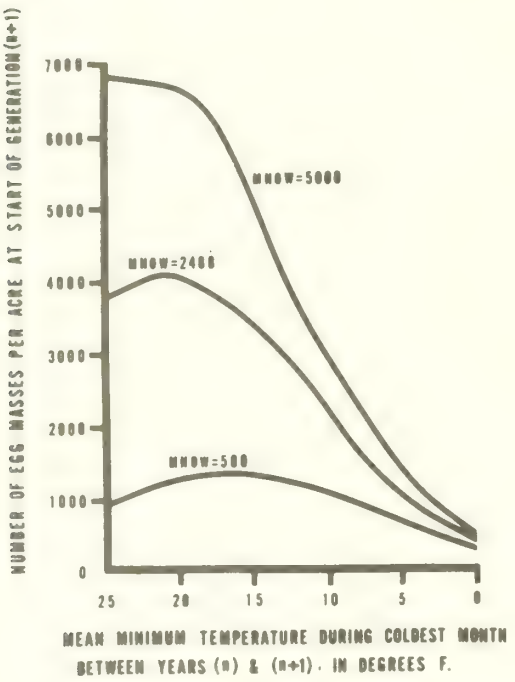


Figure 6.—Relationships between egg-mass density in the fall of year (n + 1), egg-mass density per acre in the fall of year (n) (MNOW), and the mean minimum temperature during the coldest month between years (n) and (n + 1) (TMN). Outbreak conditions.

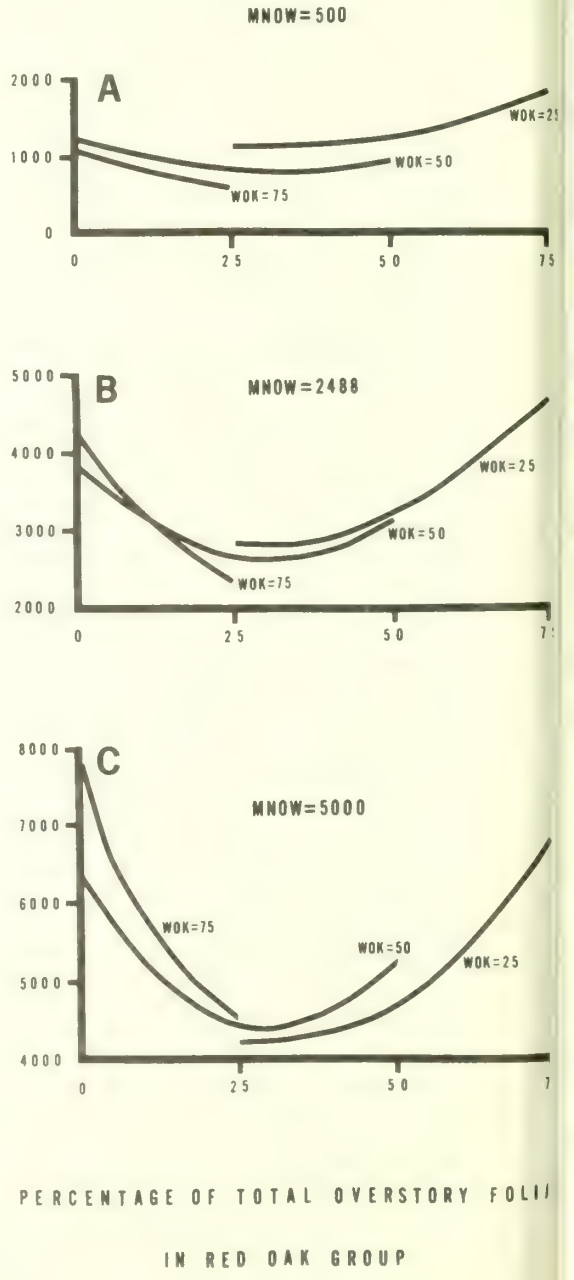



optimum mean minimum temperature for the gypsy moth apparently varied as a function of current egg-mass density. Both these relationships may imply that mechanisms similar to those described by Wellington *(1965)* for the western tent caterpillar, *Malascosoma pluviale* (Dyar), and by Morris *(1969)* for the fall webworm, *Hyphantria cunea*, may also be operative in the dynamics of gypsy moth populations. This possibility should be explored.

*White oak (WOK), red oak (ROK), and current density (MNOW).*—Relationships between WOK, the percentage of the total overstory foliage in the white oak group; ROK, the percentage in the red oak group; and MNOW, current egg-mass density, are shown in figure 7. (At least one-half of the total overstory foliage had to be in oak for a stand to be within this stratum, and this figure reflects this constraint.)

Higher egg-mass densities could be expected in stands composed primarily of red oak than

Figure 7.—Relationship between egg-mass density in the fall of year (n + 1) (MNXTYR) and the percentages of the total overstory foliage in the red oak group (ROK) and the white oak group (WOK). A, Relationship between MNXTYR, ROK, and WOK when egg-mass density per acre in the fall of year (n), (MNOW) is held constant at 500 egg masses per acre. B, Relationships between MNXTYR, ROK, and WOK when MNOW is held constant at 2,488 egg masses per acre. C, Relationships between MNXTYR, ROK, and WOK when MNOW is held constant at 5,000 egg masses per acre. Outbreak conditions.



in those composed primarily of white oak when current density was about 500 egg masses per acre (fig. 7A), but this relationship reversed when current density was about 5,000 egg masses per acre (fig. 7C). A transition stage is shown between these two extremes, when current density was about 2,500 egg masses per acre (fig. 7B).

In the first case, stands composed primarily of trees in the red oak group may have provided a larger number of resting locations for gypsy moth larvae where these insects were relatively safe from predators than did their counterparts in the white oak group.

When current egg-mass density reached 5,000 egg masses per acre, gypsy moth egg-mass density tended to be higher in year (n + 1) in stands composed primarily of white oaks than in those composed primarily of the red oak group. One reason for this may be that the insect tends to complete its development somewhat more rapidly, within any given field population, on white oak than on red oak, at least when population density is high *(Campbell 1961)*. This differential development rate could have been critically important in determining generation survivorship, especially when defoliation by the insect approached 100 percent.

*Food class C (FCC).*—Egg-mass density was reduced as FCC, the percentage of the overstory foliage that is usually unpalatable to gypsy moth larvae, increased (fig. 8). This result is in complete accord with many previous observations in this country, going back to those summarized by Mosher *(1915)*.

*Defoliation of food class A in year (n) (DCA(n) ).*—Density decreased in the fall of year (n + 1) as defoliation of the favored food trees increased in the preceding summer (fig. 9). This relationship probably reflects the reduction in the average number of eggs in each egg mass in the fall of year (n) as defoliation increased during the summer of that same year. It may also reflect on the physiological state of the larvae issuing in the spring of year (n + 1).

*Overall defoliation in year (n + 1) (DEF(n + 1) ).*—Relationships between egg-mass density in the fall of year (n), subsequent defoliation in the summer of year (n +

Figure 8.—Relationships between egg-mass density in the fall of year (n + 1), the percentage of the total overstory in class C food, (FCC), and the percentage of the acres in the zone in the fall of year (n) containing more than 500 egg masses per acre (ZDL). Outbreak conditions.

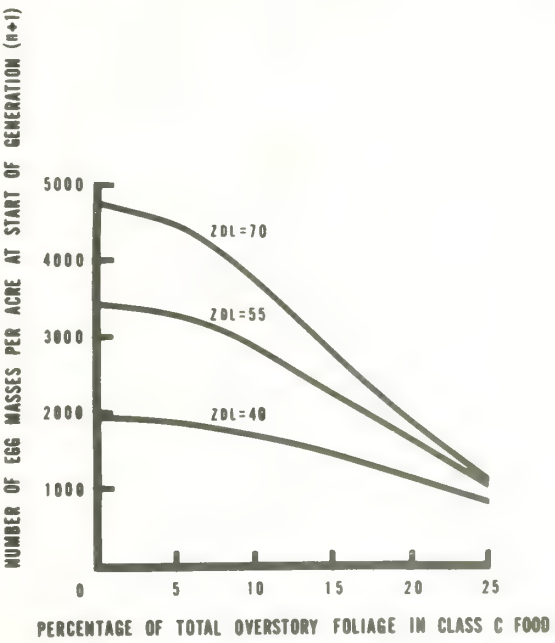



Figure 9.—Relationships between egg-mass density in the fall of year (n + 1), egg-mass density per acre in the fall of year (n) (MNOW), and percentage defoliation of class A food trees during year (n) (DCA(n)). Outbreak conditions.

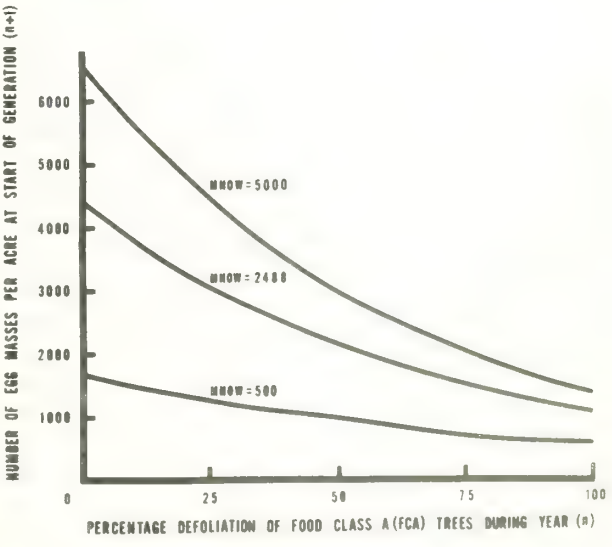
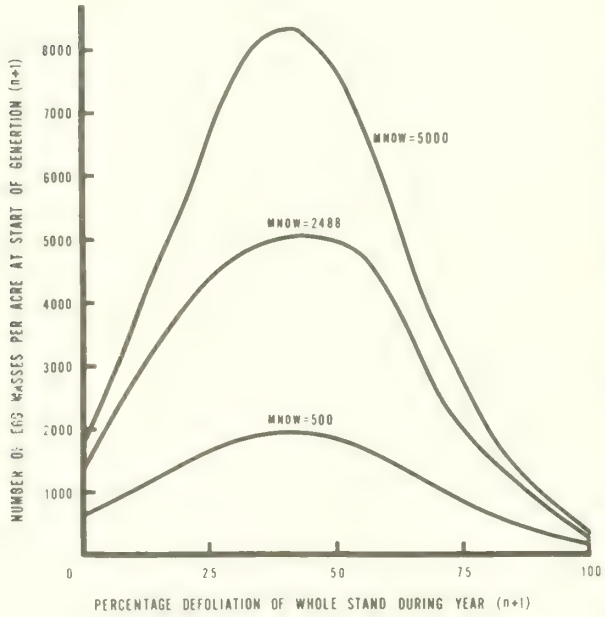


Figure 10.—Relationships between egg-mass density in the fall of year (n + 1), egg-mass density per acre in the fall of year (n) (MNOW), and percentage defoliation of the whole stand during the summer of year (n + 1), (DEF (n + 1). Outbreak conditions.




1), and egg-mass density in the fall of year (n + 1) are shown in figure 10. Although density clearly tended to decrease dramatically as defoliation approached 100 percent, it also tended to decrease as defoliation approached zero.

Density undoubtedly tended to decrease as defoliation approached 100 percent not only because the insect was exhausting its food base, but also because the incidence of disease, desiccation, and stinging by ichneumonid wasps all tend to increase dramatically under these conditions *(Campbell 1963a and (1963b)*; and since all these mortality factors also tend to kill more female than male insects, their real effects would be magnified even more. This mechanism could reduce an OUTBREAK phase to an INNOCUOUS one, although widespread and extremely heavy defoliation would both be prerequisites.

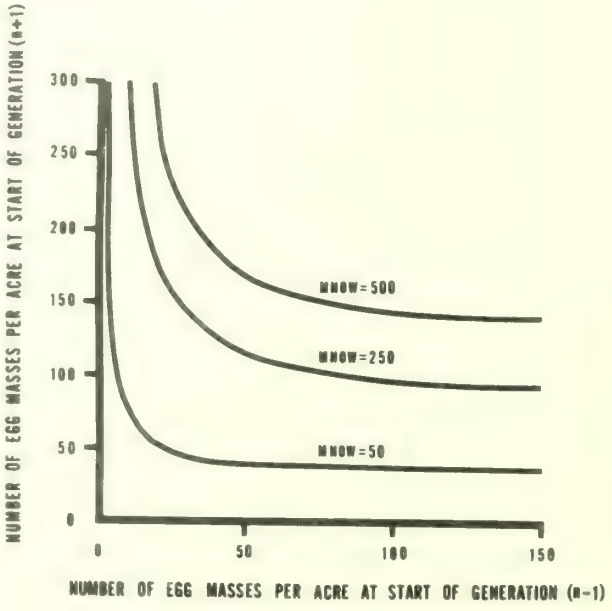
Finally, why should population density have tended to decrease as defoliation approached zero? Although this phenomenon appears to be relatively common, it has been mentioned only briefly in the literature, and no mechanisms have been proposed that might account for it. Here is a problem that should be examined as soon as possible.

## Site Density Under INNOCUOUS Conditions

Figures 11 to 18 represent expected values of gypsy moth egg-mass density under INNOCUOUS conditions, wherein both low zone density and high zone density are set at zero; prior egg-mass density (MLSTYR) is set at 50 egg masses per acre unless otherwise specified; and the other independent variables are allowed to vary.

*Egg-mass densities (MLSTYR) and (MNOW).*—Egg-mass density in the fall of year (n + 1) (MNXTYR) is shown as a function of current density (MNOW) and density in the fall of year (n — 1) (MLSTYR) in figure 11. Density only tended to increase from year (n) to (n + 1) if it had already increased several fold from year (n — 1) to (n) and population density, in general, tended to stabilize at less than 50 egg masses per acre under these INNOCUOUS conditions. Recent stud-

Figure 11.—Relationships between egg-mass density per acre in the fall of year (n + 1), and egg-mass densities per acre in the fall of year (n — 1) and (n) (MLSTYR and MNOW). Innocuous conditions.



ies suggest that this low-level stability may have been achieved largely through the activities of vertebrate predators *(Campbell 1967b)*.

*Precipitation in May of year (n) (PM).*—The relationship between precipitation in May of year (n) and egg-mass density in the fall of year (n + 1) is shown in figure 12, with both prior and current densities held at 50 egg masses per acre. Even when no rainfall occurred in May of year (n), only about 60 egg masses could be expected per acre in the fall of year (n + 1), so this relationship was probably not biologically significant during the INNOCUOUS phase.

Figure 12.—Relationships between egg-mass density in the fall of year (n + 1) and precipitation in May of year (n) (PM). Innocuous conditions.

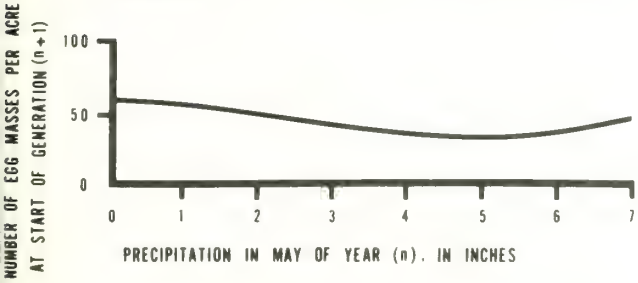



Figure 13.—Relationships between egg-mass density in the fall of year (n + 1), precipitation in June of year (n + 1) (RJ), and the percentage of the acres in the zone in the fall of year (n) containing more than 500 egg masses per acre (ZDL). Innocuous conditions.

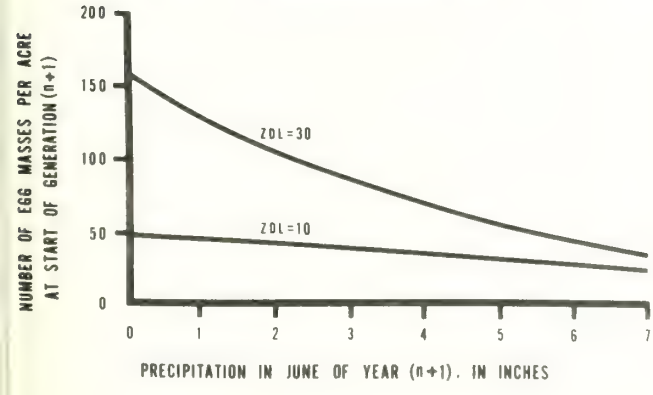
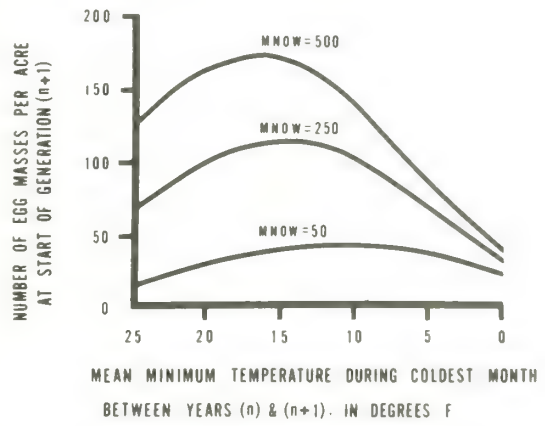



Figure 14.—Relationships between egg-mass density in the fall of year (n) (MNOW), and the mean minimum temperature during the coldest month between years (n) and (n + 1) (TMN). Innocuous conditions.




*Precipitation in June of year (n + 1) (RJ).*—Relationships between precipitation in June of year (n + 1), low zone density in the fall of year (n), and subsequent egg-mass density in the fall of year (n + 1) are shown in figure 13. Apparently this precipitation variable, like precipitation in May of year (n), was not biologically significant within the INNOCUOUS range.

*Mean minimum winter temperature (TMN).*—Gypsy moth density in year (n + 1) was not particularly responsive to variation in the mean minimum winter temperature during the coldest month between year (n) and (n + 1) (fig. 14). Thus this variable, like precipitation, was probably not biologically significant within the INNOCUOUS range, except when exceptionally low temperature regimes were maintained.

*White oak (WOK), red oak (ROK), and current density (MNOW).*—Relationships between the percentage of the total overstory foliage in the white oak group (WOK), the percentage of this total in the red oak group (ROK), the current number of egg masses per acre (MNOW), and the number of egg masses per acre in the fall of year (n + 1) (MNXTYR) are shown in figure 15. Although stands composed primarily of red oak group trees consistently tended to produce higher

Figure 15.—Relationships between egg-mass density in the fall of year (n + 1) (MNXTYR) and the percentages of the total overstory foliage in: (a) the red oak group (ROK) and (b) the white oak group (WOK). A, Relationships between MNXTYR, ROK, and WOK when egg-mass density per acre in the fall of year (n) (MNOW) is held constant at 50 egg masses per acre. B, Relationships between MNXTYR, ROK, and WOK when MNOW is held constant at 250 egg masses per acre. C, Relationships between MNXTYR, ROK, and WOK when MNOW is held constant at 500 egg masses per acre. Innocuous conditions.

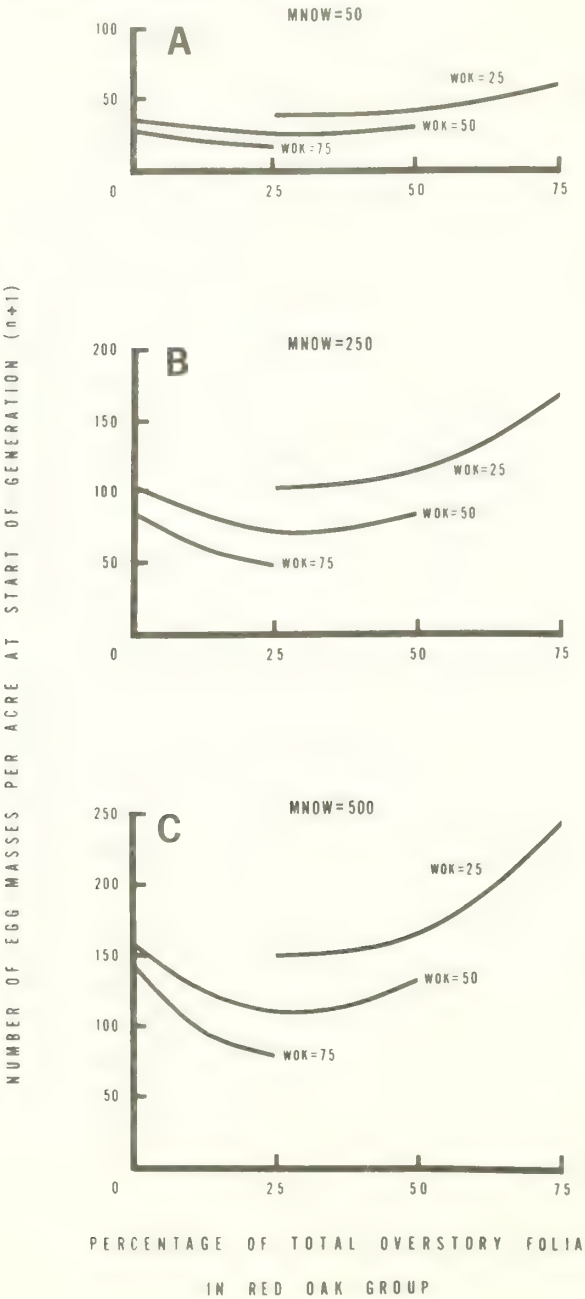
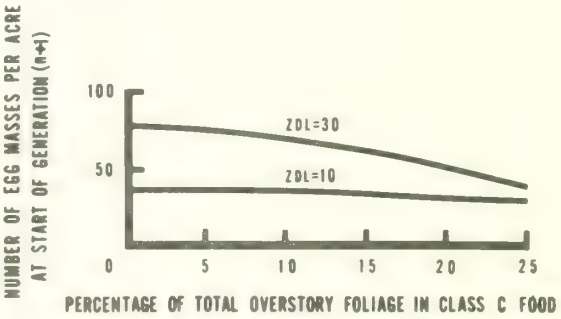



Figure 16.—Relationships between egg-mass density in the fall of year (n + 1), the percentage of the total overstory in class C food (FCC), and the percentage of the acres in the zone in the fall of year (n) containing more than 500 egg masses per acre (ZDL). Innocuous conditions.




egg-mass densities than those composed primarily of trees from the white oak group, egg-mass densities tended to be reduced from year (n) to (n + 1) under any combination of these overstory variables if they had chanced to reach 250 or more egg masses per acre in the fall of year (n). Thus variation in the overstory composition does not appear to include a mechanism through which the population system could reach the OUTBREAK-phase.

*Food class C (FCC).*—Variation in the amount of class C food bore almost no relationship to egg-mass density in the fall of year (n + 1) under INNOCUOUS conditions (fig. 16).

*Defoliation of food class A in year (n) (DCA(n) ).*—Relationships between defoliation of class A food in year (n) and egg-mass density in the fall of year (n + 1) are shown in figure 17. The relationship shown indicates that egg-mass density could not be expected to increase out of the INNOCUOUS range under any previous defoliation regime.

*Overall defoliation in year (n + 1 — (DEF(n = 1) ).*—Finally, relationships between defoliation in the summer of year (n + 1) and egg-mass density in the fall of that year are shown in figure 18. Although egg-mass density tended to be highest in year (n + 1) following defoliation of about 40 percent of the overstory, the model indicates that even

Figure 17.—Relationships between egg-mass density in the fall of year (n + 1), egg-mass density per acre in the fall of year (n) (MNOW), and percentage defoliation of class A trees during year (n) (DCA(n)). Innocuous conditions.

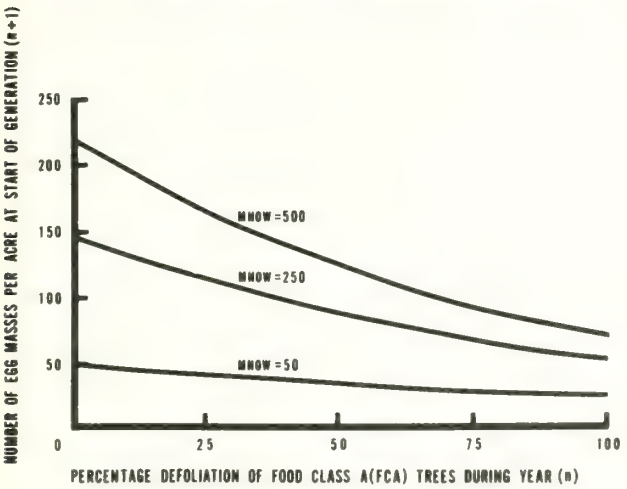
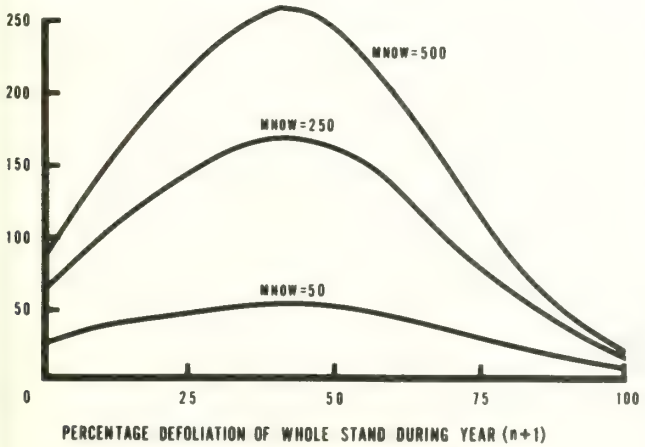



Figure 18.—Relationships between egg-mass density in the fall of year (n + 1), egg-mass density per acre in the fall of year (n) (MNOW), and percentage defoliation of the whole stand during the summer of year (n + 1) (DEF (n + 1). Innocuous conditions.




this highest density represented about a two-fold reduction in egg-mass density from year (n) to (n+ 1) if about 500 egg masses were present per acre in the fall of year (n).

# DISCUSSION

The model just described leads toward four general conclusions about the behavior of the gypsy moth population system between 1911 and 1931 in eastern New England.

*First*, once the system reached a sufficiently high overall density, a massive outbreak could be expected to continue for many years.

*Second*, almost any woodland environment, regardless of its inherent capacity to maintain gypsy moth populations within a sparse range, would probably have been characterized, at times, by a high density resident gypsy moth population, if it were located in the vicinity of a massive outbreak.

*Third*, the system was relatively stable in either the OUTBREAK phase or the INNOCUOUS one, but it showed no tendency toward, or capacity for, stability within any intermediate phase. Local isolated outbreaks were much more likely to subside within a year or two to the INNOCUOUS phase than to expand to the OUTBREAK phase, while isolated low-density populations tended to increase rapidly to high density levels during the OUTBREAK phase.

*Fourth*, this model does not indicate mechanisms sufficient to change the system from the INNOCUOUS phase to the OUTBREAK one. Both a raitonale for each of the above conclusions and the implications arising from each one are described below.

Conclusions one and two are truly alarming, because they imply that a massive outbreak by this insect, left alone, may not only persist for many years, but also will probably expand in size.

This conclusion is difficult to verify or deny, because man has seldom left massive woodland outbreaks by this pest untreated, yet the population system that was studied in Glenville, New York, between 1958 and 1964 remained in the OUTBREAK phase for about 8 years and tended to expand during this time. A similar situation, on a truly massive scale, may also have developed in southern Connecticut, southern New York state, New Jersey, and eastern Pennsylvania in recent years.

Both the model and the experience of specialists in the management of this pest indicate that treatment applied piecemeal to ex-

ceptionally high-density populations does not cope with the underlying problem during the OUTBREAK phase. Such spot treatments can usually be relied upon to save foliage and to keep trees alive that might otherwise be lost, but that is *all* they can be relied upon to accomplish. Indeed, many spots can be found within any massive outbreak that have been treated several times—at intervals ranging from 2 to 5 years.

Options for coping with a massive outbreak of this pest are limited.

(1) We can do nothing, and hope that one of the following naturally occurring processes will terminate the OUTBREAK phase:

- Populations will increase explosively to extremely high levels from year (n — 1) to (n) and then recede abruptly to innocuous levels in year (n + 1).
- The area covered by the entire OUTBREAK system will be virtually stripped of its foliage in the summer of year (n + 1), and subsequent density levels will return to the INNOCUOUS phase.
- Precipitation will be extremely high in June of year (n + 1) across the entire area.
- The mean minimum winter temperature during the coldest month between years (n) and (n + 1) will approach zero °F. across the entire area.

(2) Or we can continue to treat places where the values threatened by the insect are known to exceed both the known direct cost and estimated indirect costs of control, in the knowledge that such treatments will not solve the underlying problem.

Clearly, what is really needed here is an environmentally acceptable treatment that could be applied *effectively* to the entire massive outbreak, but no such treatment is now available.

The fact that we are dealing with an apparently two-phase system, INNOCUOUS or OUTBREAK, is encouraging. This implies that both research and control work can be planned to cope with one phase or the other, with the knowledge beforehand that this system will transit rapidly to one phase or the other even if it happens to be in a transient state when work is initiated. Further, the model implies that the state of the system in year (n + 1) could have been forecast accurately between 1911 and 1931 just by knowing zone density in year (n).

Finally, the model failed to indicate a mechanism through which the INNOCUOUS phase might be transformed to the OUTBREAK one, except through increasing the general density level of the system, presumably through an overlap between areas in the OUTBREAK and INNOCUOUS phases. This is unfortunate because the ideal way to manage this population system would be to prevent outbreaks from occurring, but we can only hope to specify strategies through which this management goal could be achieved after these mechanisms have been discovered. A clue to the physical whereabouts of one such mechanism may be attributed to Forbush and Fernald *(1896)*, who wrote that:

> The study of the infested territory made in 1891 showed that the most densely infested areas were very nearly coincident with the centers of [human] population. In other words the moth colonies were larger and more numerous in or near thickly populated districts.

In short, one answer to this puzzle may be found literally in our own backyards, and we are now establishing a plot system in suburban areas to evaluate this possibility.

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# APPENDIX

Mean values of the independent variables used to calculate figures 1 to 18.

| *Variable* | *Mean value* |
|---|---|
| Current egg-mass density (MNOW) | 2,448 egg masses per acre |
| Prior egg-mass density (MLSTYR) | 2,705 egg masses per acre |
| Low zone density (ZDL) | 53 percent |
| High zone density (ZDH) | 14 percent |
| Precipitation in May of year (n) (PM) | 3.17 inches |
| Precipitation in June of year (n + 1) (RJ) | 3.59 inches |
| Mean minimum winter temperature (TMN) | 14°F |
| White oak group (WOK) | 24 percent |
| Red oak group (ROK) | 51 percent |
| Food class C (FCC) | 0.4 percent |
| Prior defoliation (DCA(n)) | 22 percent |
| Current defoliation (DEF (n + 1)) | 16 percent |



☆U.S. GPO: 1973—711-424/527

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

1. RP-NE-269 Shafer, Elwood L., Jr., and Thomas A. Richards. 1973. A comparison of viewer reactions to outdoor scenes and photographs of those scenes. NE. Forest Exp. Sta., Upper Darby, Pa. (USDA Forest Serv. Res. Pap. NE-269)

Research Paper NE-269 has been dropped from our publications available --Abstract Sheet No. 7--1973.

Publication has been delayed until further notice. The publication will be available later, and will be advertised on our abstract sheet with a NEW Research Paper number.

# STRUCTURE OF AN URBAN CHRISTMAS TREE MARKET

AUG 4 1971
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by Thomas H. Pendleton
and Lawrence D. Garrett

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6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

892.51

## THE AUTHORS

THOMAS H. PENDLETON is an economist at the Northeastern Forest Experiment Station's Forest Products Marketing Laboratory in Princeton, W. Va. He holds B.A. and B.S. degrees from West Virginia University and an M.A. degree from The George Washington University. He is a candidate for the Ph.D. degree in economics at the University of Tennessee. Before joining the Forest Service in 1967, he was assistant professor of economics at Concord College.

LAWRENCE D. GARRETT is a forest economist and project leader for research at the Northeastern Forest Experiment Station in Burlington, Vt. When this study was made, he was at the Station's Forest Products Marketing Laboratory in Princeton, W. Va. He received his B.S. degree from Southern Illinois University and his M.S. degree from Michigan State University. He is a candidate for the Ph.D. degree in forestry economics at Michigan State University. He began his career with the Forest Service in 1965.

MANUSCRIPT RECEIVED FOR PUBLICATION 5 JANUARY 1973

# STRUCTURE OF AN URBAN CHRISTMAS TREE MARKET


## ABSTRACT

The retail Christmas tree market in Winston-Salem, N. C., was studied 3 years. Types of retailers and their sales are described. Best sales were made by dealers who had lots on heavily traveled streets in business districts, had ample parking facilities, advertised, and displayed their trees well.

GROWING AND SELLING Christmas trees is big business in the United States. Thousands of growers supply an even larger number of wholesalers and retailers with about 40 million natural Christmas trees each year. Consumers spend nearly $200 million for these evergreens. An additional 5 to 6 million artificial trees are sold at retail each year for more than $65 million.

To sell this many natural Christmas trees in just a few weeks requires an efficient marketing system. Producers of natural trees must quickly move their products to dealers located in the thousands of markets across the country. These dealers in turn must find buyers for the trees before Christmas day. From producer to consumer, distribution must be fast and efficient. No one wants to be caught with leftover trees on Christmas day.

To gain a better understanding of how natural Christmas trees are marketed, we studied an urban Christmas tree retail market. Information was sought about the nature and degree of concentration of Christmas tree retailers, conditions of entry into the market, retail price policies, location characteristics, and promotional techniques.

## THE STUDY

During the 1967, 1968, and 1969 Christmas seasons, a survey was made of all natural Christmas tree retailers in Winston-Salem, North Carolina. All tree retailers were visited each year, and their operations were observed.

After the selling season, each retailer was asked to provide information about his Christmas tree business. In this way, data were obtained on tree sales and prices, types and locations of retail outlets, and marketing techniques. Analysis of these data provided information about the structure of the Winston-Salem Christmas tree retail market.

# THE MARKET

## The Urban Area

Winston-Salem is located on the Piedmont Plateau in northwestern North Carolina. In 1970, the population of the city plus urban fringe was about 170,000. Almost 130,000 of these resided within the city limits. The number of households in the city was nearly 45,000. The age distribution of the population was similar to that for the United States.

The per-capita disposable income for Winston-Salem in 1968 was about $2,800, slightly below the national average. Disposable income per household was about $9,500. However, like most urban areas, geographical income differences were extreme. In the affluent sections in the western part of the city, average household disposable income was over $20,000, and in certain sections in the central and eastern parts of the city, disposable income was less than $3,000.

## Sales

Christmas tree retailers in Winston-Salem sold about 9,000 natural trees in 1967, 10,000 in 1968, and 12,000 in 1969 (table 1). Balsam fir was by far the biggest seller each year, accounting for more than 40 percent of all trees sold.

In 1967, eastern red cedar and white pine were second and third in sales, respectively. By 1969, the cedar had slipped to fifth in popularity. White pine was the second most popular tree in 1969, followed by Fraser fir and Scotch pine. The large decline in sale of cedars was attributed to an increase in the supply of the better-quality pines and firs. Sales of Fraser fir doubled between 1967 and 1969.

Unsold trees varied from about 15 percent of the stock in 1967 to about 10 percent in 1968 and 18 percent in 1969. Eastern red cedar led the list of unsold trees. Lot operators had to discard about one-fifth of their cedars each year. Generally, fewer Scotch pines had to be discarded than any other species.

(About 17,000 artificial Christmas trees were used in Winston-Salem in 1969. About 25 percent of these trees were bought new in 1969.)

## Prices

The retail price of Christmas trees varied according to species (table 2); but of all the major species, Fraser fir brought the highest price each year.

The average percentage retail markup of the five major species declined notably over the 3 years, from 118 percent in 1967 to 98 percent in 1968 and 91 percent in 1969. Generally, white pine and cedar had the highest markups. The high-priced Fraser fir had the smallest markup each year. A relatively large increase in wholesale tree prices was responsible for the decline in markups.

Table 1.—*Christmas tree sales in Winston-Salem, North Carolina, 1967-69*

| Type | 1967 | | 1968 | | 1969 | |
|---|---|---|---|---|---|---|
| | Number | Percent of trees available | Number | Percent of trees available | Number | Percent of trees available |
| Balsam fir | 3,762 | 89.6 | 4,529 | 92.2 | 5,173 | 81.7 |
| White pine | 1,566 | 84.1 | 1,737 | 87.1 | 2,075 | 81.3 |
| Fraser fir | 615 | 82.4 | 848 | 96.4 | 1,382 | 83.7 |
| Scotch pine | 976 | 95.2 | 1,305 | 93.2 | 1,304 | 87.1 |
| Eastern red cedar | 1,686 | 77.3 | 1,097 | 81.4 | 900 | 78.5 |
| Blue spruce | — | — | — | — | 83 | 87.4 |
| Norway spruce | 16 | 100.0 | 3 | 15.0 | 65 | 81.2 |
| Douglas-fir | — | — | — | — | 57 | 95.0 |
| White spruce | 35 | 70.0 | — | — | — | — |
| Arizona cypress | 40 | 66.7 | — | — | — | — |
| Halvorson[1] | 531 | 77.8 | 633 | 95.6 | 902 | 85.5 |
| Total | 9,227 | 85.3 | 10,152 | 90.3 | 11,941 | 82.5 |

[1]A color-processed natural spruce.

Table 2.—*Average retail price of Christmas trees in Winston-Salem, 1967-69*

| Species | 1967 | 1968 | 1969 |
|---|---|---|---|
| Balsam fir | $2.84 | $3.10 | $3.34 |
| White pine | 4.44 | 4.69 | 4.19 |
| Fraser fir | 4.81 | 6.73 | 6.90 |
| Scotch pine | 4.55 | 4.76 | 4.11 |
| Eastern red cedar | 2.08 | 2.32 | 2.86 |
| Blue spruce | — | — | 4.00 |
| Norway spruce | 3.25 | — | — |
| Douglas-fir | — | — | 7.00 |
| White spruce | 2.00 | — | — |
| Arizona cypress | 1.10 | — | — |
| Halvorson | 2.00 | 2.32 | 2.08 |
| Average | $3.21 | $3.75 | $3.87 |

Chain grocery stores and discount stores sold Christmas trees at below-average markups. Trees sold by nurseries and florists carried the highest markups.

# THE RETAIL STRUCTURE

There were 53 Christmas tree retailers in Winston-Salem in both 1967 and 1969. Only 46 retailers sold Christmas trees in 1968.

## Type of Retailers

Many different types of retail outlets sold Christmas trees in Winston-Salem between 1967 and 1969. Each year, over one-third of all Christmas tree retailers were chain grocery stores. Independent sales lots (including those operated by church and civic groups) accounted for about 22 percent of the retailers, discount stores for about 13 percent; independent grocers, nurseries and florists, service stations, and other dealers made up about 30 percent.

The proportion of sales for the different types of retailers was as follows:

| *Type of retailer* | *Sales (percent)* |
|---|---|
| Chain groceries | 25.9 |
| Independent lots | 44.4 |
| Discount stores | 15.4 |
| Independent grocers | 2.6 |
| Nurseries and florists | 5.3 |
| Service stations | 3.8 |
| Other | 2.6 |
| | 100.0 |

In 1969, eight retail organizations each operated two or more Christmas tree outlets. Five of these were major food chains. There were nine retail organizations with more than one outlet in 1967 and seven in 1968. In each of the 3 years, about one-half of all outlets belonged to some type of chain organization. These retail outlets sold about 35 percent of all the trees sold each year.

## Size of Retailers

The Winston-Salem market was characterized by a few large tree retailers and many small ones. In each of the 3 years, the 10 largest retailers—roughly 20 percent of all retailers—sold about 60 percent of all the trees sold. In 1969, each of the 10 largest retailers sold an average of 722 trees. All other retailers averaged less than 110 trees each.

## Ease of Entry and Exit

The retail Christmas tree market in Winston-Salem was characterized by ease of entry and exit of sellers. There are three reasons.

- The only major investment required of the retailer is an inventory of trees. And because the selling season is short, the investment is recovered quickly. No permanent facilities are needed.
- The trees of one retailer are very much like the trees of any other; so consumers have no reason to think that one retailer will have better trees than any other.
- The supply of Christmas trees for sale at wholesale in Winston-Salem was more than adequate for the existing demand. Accordingly, new retailers had no difficulty in obtaining a sufficient quantity of suitable trees.

The lack of barriers to entry and exit was clearly evident in Winston-Salem between 1967 and 1969. Between 1967 and 1968, 13 retailers left and 6 entered. And between 1968 and 1969, 11 retailers entered and 4 left. Of the 65 different retailers who sold trees between 1967 and 1969, 35 percent lasted just 1 year. Only 37 retailers—57 percent—were in the tree business all 3 years.

The small retail outlets were responsible for most of the fluctuation in the number of retailers; large operators seldom left the busi-

ness. The average sales of those retailers that left the business was only about 100 trees. All but one of the 10 largest retailers in 1967 were still in business in 1968. And all of the 10 largest retailers in 1968 were still selling trees in 1969.

## LOT LOCATION

Business areas and major traffic arteries have one thing in common — people. And people demand goods and services, including Christmas trees. Retail Christmas tree outlets that are located where consumer demand is large can be expected to sell more trees and sell them at higher prices.

### Type of Area

Most Christmas tree retailers — 70 to 80 percent — in Winston-Salem were located in business areas. About one-third of all retailers were located in shopping centers each year. Every one of the 10 largest retailers in 1968 and 1969 was located in a business area.

Retailers located in business areas sold more trees and discarded fewer each year than did those in residential areas (fig. 1). In 1968, the typical residential retailer sold only 98 trees and had to discard 1 tree for every 4 trees sold. In 1969, the average retailer in a business area sold 241 trees, but the average retailer in a residential area only sold 156 trees.

In addition to selling more trees, retailers in business areas received a higher price for their trees. For example, in 1969, the average price of trees sold in business areas was $4.04; the price in residential areas was $3.76.

### Type of Street

About half of all Christmas tree retailers in Winston-Salem were located on major traffic arteries (average daily volume of more than 10,000 vehicles). These retailers sold more than twice as many trees as retailers located on streets with less traffic. Eight of the 10 largest retailers were located on major streets in both 1968 and 1969.

Prices were also higher at outlets located on major streets. In 1969, the average price of trees sold by retailers on major streets was $4.24, or $0.87 higher than tree prices at retail outlets on minor streets. The average price differences in 1967 and 1968 were $0.51 and $1.12, respectively.

Figure 1.—A Christmas tree retailer located in a residential area cannot expect to sell many trees.

Over the 3-year period, the proportion of Christmas tree retailers located on major traffic arteries gradually increased. This trend will probably continue as more and more retailers realize the importance of selling trees where consumers concentrate.

### Parking Facilities

Buyers of natural Christmas trees seem to prefer the convenience of large and easily accessible parking lots. Retailers providing adequate parking sold over twice as many trees than did other retailers. And they had fewer trees left over on Christmas day. For example, in 1969, retailers without adequate parking facilities had to discard two trees for every three sold.

Tree prices were also higher at locations with large parking areas. Tree buyers were apparently willing to pay for convenient parking facilities.

Most Christmas tree retailers in Winston-Salem realized the importance of large and easily accessible parking facilities. About 70

percent of the retail outlets had adequate parking facilities. The others had either small and cramped parking lots or none at all.

## PROMOTION

Advertising and product display were the most widely used methods for promoting sale of Christmas trees in Winston-Salem.

### Advertising

About half of all retailers advertised their Christmas trees each year. This advertising included newspaper, television, and radio ads; handbills; trading-stamp specials; special displays; and direct-mail campaigns.

Newspaper advertising was the most common. In 1967, about 40 percent of the retailers advertised in newspapers, and in 1968 and 1969, the number was almost 50 percent. Newspaper advertising was used heavily by chain grocery stores and discount stores.

Christmas tree retailers made very little use of radio and television to reach the public. In 1969, only six retailers used either one of these two media. Three of these retailers were independent lots and all were large. In 1968, four of the five users of radio and television advertising were large independent lots.

The advertising media were used by Christmas tree retailers as follows:

| | *Percent of retailers using medium* | | |
|---|---|---|---|
| *Medium* | *1967* | *1968* | *1969* |
| Newspapers | 39.6 | 47.8 | 47.2 |
| Television | 7.5 | 6.5 | 7.6 |
| Radio | 5.7 | 10.9 | 11.3 |
| Handbills | 3.8 | 4.3 | 3.8 |
| Other | 3.8 | 8.7 | 1.9 |

In 1968, each retailer who advertised sold an average of 337 trees and had less than 7 percent of his trees left over on Christmas day. The typical retailer who did not advertise sold only 105 trees and had almost 20 percent of his trees left over. The retailer who advertised in 1969 sold an average of 312 trees compared to an average of 225 trees for all retailers. Each year, most of the 10 largest retailers advertised.

Tree prices were generally higher at retail outlets that advertised. In 1969, the average price received by retailers who advertised was $0.19 above that received by those who did not advertise. The average price differences in 1967 and 1968 were $0.35 and $0.64, respectively. Retailers who advertised eastern red cedar in 1968 were able to get at least $1.00 more than the average price for all cedars sold that year.

### Product Display

Like advertising, an attractive display of Christmas trees lures customers to retail lots and influences their decision to buy. However,

Figure 2.—An attractive display of Christmas trees and plenty of parking space lures customers to retail outlets and influences their decision to buy.

Christmas tree retailers in the Winston-Salem market—including the very largest—did not take full advantage of this promotional technique. Many—41 percent in 1969—simply leaned their trees against a building, racks, or rope. And over one-third of the retailers piled most of their trees on the ground. Only one-fourth of the retailers displayed their trees standing upright and separately for ease of selection (fig. 2).

The manner in which Christmas trees were displayed on the lot in Winston-Salem appeared to affect both tree sales and prices. Generally, a retailer whose trees stood upright and separately sold over twice as many trees as a retailer who leaned his trees against a support or stacked them in piles on the ground. Retailers with good displays also received higher prices for their trees.

## SUMMARY

Christmas tree retailers in Winston-Salem were characterized by extremes in both type and size. Grocery stores, discount houses, church and civic groups, nurseries and florists, service stations, and even individuals had trees for sale. Most of the retailers were chain grocery stores. However, the independent lots sold the most trees. Though most of the retailers were small, a few large retailers dominated the market. And because these large retailers seldom left the Christmas tree business, they provided an element of stability to a market where the turnover of retailers from one year to the next was high.

Christmas tree retailers who were located on heavily traveled streets in business areas, advertised, and had attractive tree displays and adequate parking facilities sold the most trees. These retailers also received higher prices for their trees.

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# The TIMBER-SUPPLY POTENTIAL of INTENSIVE MANAGEMENT in Upland Oak Forests of Ohio

by David A. Gansner
and Owen W. Herrick

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WARREN T. DOOLITTLE, DIRECTOR

911 : 176.1 [*Quercus* + *Carya* spp.]--(771)

## The Authors

DAVID A. GANSNER is leader of the Northeastern Forest Experiment Station's Regional Production Economics Research Work Unit at Upper Darby, Pennsylvania. He received his degree in forestry from the University of Missouri in 1958, a master's degree in agriculture economics from Ohio State University in 1968, and a master's degree in regional science from the University of Pennsylvania in 1970. He has been with the U.S. Forest Service since 1958.

OWEN W. HERRICK received his bachelor of science degree at Iowa State University and a master of forestry degree at Yale University. He has done graduate study in regional systems analysis at The Pennsylvania State University. At present he is a research forester in the Regional Production Economics Work Unit at the Northeastern Forest Experiment Station, Upper Darby, Pa.

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# The TIMBER-SUPPLY POTENTIAL of INTENSIVE MANAGEMENT in Upland Oak Forests of Ohio


## ABSTRACT

Two alternative programs of intensive timber management were defined for Ohio's oak-hickory forests. Their potentials were evaluated by comparing the expected yields and yield values of each program with those expected from a continuation of current management practices. Neither program would produce large increases in timber yield. But the expected gains in yield value would be substantial.

Figure 1.—The Hill Country of Ohio, where the study was made.

THE USDA Forest Service is conducting a timber review designed to reassess the outlook for timber supplies in the United States. One objective of this review is to estimate the potential effect of a program of intensive timber management on timber yields for the next 50 years. Yields and yield values from an intensive program will be compared with those resulting from a continuation of current management practices.

Pilot studies to develop procedures for this task were conducted for various forest types in selected regions of the Nation. This is a report on results from one of those studies.

This investigation was concerned with intensification of timber-producing practices in oak-hickory forests of the Ohio Hill Country (fig. 1). The oak-hickory forest type is a major contributor to timber-based economic activity in the eastern United States. Meaningful information on yield response to treatment is available for this timber type. The Ohio Hill Country was selected for study because it has an extensive acreage of oak-hick-

ory forest for which recent and detailed information about timber-stand characteristics is available.

## PROCEDURE

Seven basic procedural steps were followed in the analysis.

### Management Opportunity Classes Were Identified

The Ohio Hill Country's 2.3 million acres of oak-hickory forest exhibits virtually every stage of stand condition and development. Our first task was to disaggregate this variable resource into well-defined areas that were relevant for selecting, analyzing, and evaluating timber-management practices. Thirty-six opportunity classes were identified by site index, total basal area, average d.b.h., and level of stocking in growing-stock trees (table 1), (*Gansner et al. 1973*). They represent 1.8 million acres or four-fifths of the oak-hickory forest in the Hill Country.

### Representative Stand Profiles Were Derived

The choice of specific management strategies and evaluation of their yield potentials required detailed information about the structure of forest stands in each management-opportunity class. Stand profile tables, depicting the representative (average) forest acre in each opportunity class, were developed from forest-inventory plot records. These tables provided data on the number of trees in each stand by species, d.b.h., and quality class.

### Management Strategies Were Selected

A management strategy was prescribed for each forest stand representing a management-opportunity class. These strategies were designed to grow the most high-quality sawtimber the site could produce in the shortest possible time. Specific treatments varied according to the age and condition of each representative stand, but this general guide was followed:

- Stands in the $< C$ level stocking class (table 1) are not fully utilizing their sites and cannot be expected to do so for several years. Therefore they should be regenerated as soon as possible. The resulting new stands should then be cleaned and periodically thinned so as to maximize yields and promote the rapid growth of timber to a mature stage of development.
- Stands in the C to B stocking class are adequately stocked with acceptable trees. Decisions about treating them can normally be deferred for at least 10 years.
- Stands in the B+ stocking class are fully stocked with acceptable trees. Improvement cuttings down to B-level stocking, followed by thinnings designed to promote the rapid growth and maturity of timber, should be undertaken.

Average d.b.h. was used to gage the maturity of managed stands. Maturity standards varied according to site index as follows:

| *Site index* | *Stand mature when average d.b.h. is (inches)* |
|---|---|
| 50-59 | 12 |
| 60-69 | 15 |
| 70-79 | 18 |
| 80+ | 21 |

### Stand Development Was Projected

Eventually, we wanted to compare the yields of intensive management strategies with those resulting from a continuation of current management practices. Thus projections of stand development, accounting for the response to these two actions, were made for each representative stand. Growth models developed by the Northeastern Forest Experiment Station's Timber Management work unit at Columbus, Ohio, were used for the projections. Current annual cutting rates provided by the Northeast Station's Forest Survey work unit were used to estimate the yields associated with current management practices.

Table 1.—Acreage of oak-hickory forest in the Ohio Hill Country, by management-opportunity classes

| Total basal area (sq. ft.) | Average d.b.h. of acceptable trees (inches)[a] | Site index | | | | |
|---|---|---|---|---|---|---|
| | | <50 | 50-59 | 60-69 | 70-79 | 80+ |
| | | ACCEPTABLE TREE STOCKING LEVEL C[b] | | | | |
| <40 | <11.0 | 84,100 | (60,500) ① | (104,200) ② | (40,300) ③ | (26,900) ④ |
| | 11.0+ | 3,400 | 3,400 | 3,400 | — | — |
| 40-59 | <11.0 | 13,400 | (47,100) ⑤ | (74,000) ⑥ | (23,500) ⑦ | (30,300) ⑧ |
| | 11.0+ | 3,400 | — | — | — | — |
| 60-79 | <11.0 | 6,700 | 6,700 | (16,800) ⑨ | 10,100 | 3,400 |
| | 11.0+ | — | 3,400 | 3,400 | — | — |
| 80-99 | <11.0 | — | — | — | 6,700 | 3,400 |
| | 11.0+ | — | — | 6,700 | — | — |
| 100-119 | <11.0 | — | — | — | 3,400 | — |
| | 11.0+ | — | — | — | — | 3,400 |
| 120+ | <11.0 | — | — | — | — | — |
| | 11.0+ | — | — | — | — | — |
| | | ACCEPTABLE TREE STOCKING LEVEL C TO B[b] | | | | |
| <40 | <11.0 | 3,400 | 10,100 | (16,800) ⑩ | 13,400 | 6,700 |
| | 11.0+ | — | — | — | — | — |
| 40-59 | <11.0 | 40,300 | (47,100) ⑪ | (40,300) ⑫ | (50,400) ⑬ | (26,900) ⑭ |
| | 11.0+ | — | — | — | — | — |
| 60-79 | <11.0 | 50,400 | (67,200) ⑮ | (90,800) ⑯ | (50,400) ⑰ | (43,700) ⑱ |
| | 11.0+ | — | — | — | — | — |
| 80-99 | <11.0 | 13,400 | (30,300) ⑲ | (40,300) ⑳ | (30,300) ㉑ | (16,800) ㉒ |
| | 11.0+ | — | — | — | 3,400 | — |
| 100-119 | <11.0 | 3,400 | — | 13,400 | - | 3,400 |
| | 11.0+ | — | | — | | |
| 120+ | <11.0 | — | — | 3,400 | — | |
| | 11.0+ | — | — | — | — | - |
| | | ACCEPTABLE TREE STOCKING LEVEL B+[b] | | | | |
| <40 | <11.0 | — | — | — | — | — |
| | 11.0+ | — | — | — | — | — |
| 40-59 | <11.0 | — | 6,700 | 6,700 | — | 3,400 |
| | 11.0+ | — | — | — | — | — |
| 60-79 | <11.0 | 10,100 | (37,000) ㉓ | (43,700) ㉔ | (16,800) ㉕ | 10,100 |
| | 11.0+ | — | 3,400 | — | — | — |
| 80-99 | <11.0 | 53,800 | (107,600) ㉖ | (121,000) ㉗ | (87,400) ㉘ | (63,900) ㉙ |
| | 11.0+ | — | — | — | 13,400 | |
| 100-119 | <11.0 | 26,900 | (53,800) ㉚ | (74,000) ㉛ | (67,200) ㉜ | (63,900) ㉝ |
| | 11.0+ | — | — | 3,400 | — | — |
| 120+ | <11.0 | 6,700 | 13,400 | (26,900) ㉞ | (37,000) ㉟ | (26,900) ㊱ |
| | 11.0+ | — | — | — | — | — |

[a]Acceptable trees are trees that fit the standard forest survey definition of growing stock.

[b]For definitions of B and C stocking levels, see (Roach, Benjamin A., and Samuel F. Gingrich) Timber management guide for upland central hardwoods; U.S. Forest Serv. Cent. States Forest Exp. Sta., 33 p., illus. 1962.

①Circled numbers identify the 36 opportunity classes.

## The Economic Potential of Each Management Strategy Was Evaluated

Each management strategy was evaluated in terms of its economic desirability. This required meaningful estimates of costs and returns.

*Costs.*—Two basic kinds of cost were considered and accounted for: (1) direct costs of intensive management practices, and (2) opportunity costs (value forgone) relative to a continuation of current management practices.

The *direct costs* of intensive actions were simply those expenditures required to remove unmerchantable trees in regeneration and improvement cuttings and cleanings. Equations reflecting the difficulty of the tree-removal job (in number and size of trees removed) were used to calculate the costs of regeneration and improvement cuttings. The costs of cleanings were based on current estimates of the average time and manpower required to complete this kind of work on local experimental forests. Any cut yielding less than 5 cords of net volume per acre was presumed inoperable and therefore was considered strictly a cost operation.

The *opportunity costs* were estimates of the value that would be produced by a timber stand if current management practices continue. Current annual cutting rates were used to calculate the tree removals associated with current management practices. The value of these removals and the value of the residual stand at the end of the investment period were calculated, using the yield evaluation procedure outlined below. These values represented the opportunity costs of management.

*Returns.*—Returns to each management strategy were appraised in terms of the dollar value of projected timber yields. Tree conversion values developed by the Northeastern Station's Economics work unit at Columbus, Ohio, were used to derive values reflecting the net worth of standing trees. These tree values accounted for variations in tree size, species, tree quality, management intensity, and site productivity. Application of these tree values to stand-table projections provided estimates of the value of management strategy yields.

*Economic Potential.*—Present net worth values were calculated, using a discount rate of 5 percent, for each management strategy from schedules of the amount and timing of costs and returns (See table 2 for example of one schedule.) Two assumptions about projected changes in the relative value of timber and treatment costs were considered; timber val-

Table 2.—Schedule of costs and returns[a] for management-opportunity class No. 6, in dollars per acre

| Year | Action | | Opportunity costs (value forgone) | Direct costs | Returns |
|---|---|---|---|---|---|
| 1-70 | Current management continued | | $1.90 per year | | |
| 0 | Regeneration cutting | | — | $12.70 | $75.80 |
| 10 | Cleaning | | — | 21.50 | — |
| 30 | Commercial thinning | | — | — | 12.50 |
| 42 | Commercial thinning | | — | — | 12.50 |
| 52 | Commercial thinning | | — | — | 24.70 |
| 62 | Commercial thinning | | — | — | 53.00 |
| | | Intensive management | — | — | 673.70 |
| 70 | Value of residual stand | Current management continued | 206.50 | - | - |

[a]Assuming no change in the relative value of timber or treatment costs over time.

Table 3.—Economic potential of intensive management strategies

| Management opportunity class | | | | | Management strategy | Present net worth per acre if timber values and treatment costs— | |
|---|---|---|---|---|---|---|---|
| | | Description | | | | | |
| No. | Area (acres) | Total basal area (sq. ft.) | Acceptable tree stocking level | Site index class | | Remain constant | Increase at compound rate of 2% |
| 1 | 60,500 | <40 | <C | 50-59 | | (—) | (—) |
| 2 | 104,200 | <40 | <C | 60-69 | | (—) | $ 58.50 |
| 3 | 40,300 | <40 | <C | 70-79 | | (—) | 91.90 |
| 4 | 26,900 | <40 | <C | 80+ | Regenerate, clean, | $29.30 | 198.40 |
| 5 | 47,100 | 40-59 | <C | 50-59 | periodically thin, and | 4.70 | 20.50 |
| 6 | 74,000 | 40-59 | <C | 60-69 | harvest | 37.50 | 76.80 |
| 7 | 23,500 | 40-59 | <C | 70-79 | | 35.00 | 133.10 |
| 8 | 30,300 | 40-59 | <C | 80+ | | 74.40 | 195.80 |
| 9 | 16,800 | 60-79 | <C | 60-69 | | 35.80 | 26.40 |
| 10 thru 22 | 551,300 | | C to B | | None | | |
| 23 | 37,000 | 60-79 | B+ | 50-59 | | (—) | 8.60 |
| 24 | 43,700 | 60-79 | B+ | 60-69 | | (—) | 19.00 |
| 25 | 16,800 | 60-79 | B+ | 70-79 | | 14.70 | 91.90 |
| 26 | 107,600 | 80-99 | B+ | 50-59 | | (—) | (—) |
| 27 | 121,000 | 80-99 | B+ | 60-69 | | (—) | (—) |
| 28 | 87,400 | 80-99 | B+ | 70-79 | Improvement cut, | 12.00 | 89.30 |
| 29 | 63,900 | 80-99 | B+ | 80+ | periodically thin, | 12.70 | 176.30 |
| 30 | 53,800 | 100-119 | B+ | 50-59 | and harvest | (—) | 10.20 |
| 31 | 74,000 | 100-119 | B+ | 60-69 | | (—) | (—) |
| 32 | 67,200 | 100-119 | B+ | 70-79 | | (—) | 37.70 |
| 33 | 63,900 | 100-119 | B+ | 80+ | | (—) | 118.10 |
| 34 | 26,900 | 120+ | B+ | 60-69 | | (—) | (—) |
| 35 | 37,000 | 120+ | B+ | 70-79 | | (—) | 25.90 |
| 36 | 26,900 | 120+ | B+ | 80+ | | (—) | 14.10 |

ues and treatment costs (1) remaining constant over time, and (2) increasing at a compound rate of 2 percent. A perfectly elastic demand for the products of each strategy was also assumed. In other words, all yields were presumed saleable at given prices. The resulting present net worth values provided a basis for gaging the economic potential of each strategy under the two value-cost assumptions (table 3).

## Two Alternative Programs for Intensive Management Were Defined

All management strategies yielding a positive present net worth (at a 5-percent discount rate) were considered worthy components of a program of intensive timber management. Since two assumptions about projected changes in timber value and treatment costs were considered, two alternative programs for intensive management were defined:

| *Program* | *Timber values and treatment costs* | *Area receiving intensive management* |
|---|---|---|
| A | Remain constant | 386,700 acres in 9 management opportunity classes (No. 4-9, 25, 28, and 29) |
| B | Increase @ compound rate of 2 percent | 860,700 acres in 18 management opportunity classes (No. 2-9, 23-25, 28-30, 32, 33, 35, and 36) |

### The Potential of Each Program Was Assessed

The expected yields and yield values produced over the next 50 years by programs A and B were summarized by decade (tables 4 and 5). Results of a continuation of current management practices on all oak-hickory forests in the Hill Country were also estimated for the same time period (table 6). Yields and yield values produced by each program were compared with those resulting from a continuation of current management practices. This comparison provided the measure of program potential.

## RESULTS

Two programs of intensive timber management were defined for oak-hickory forests in the Hill Country of Ohio. Each reflects different assumptions about projected changes in the relative value of timber and treatment costs. Program A is based on the assumption that timber values and treatment costs will not change. Program B is based on the assumption that values and costs will increase at

Table 4.—Projected results of implementing program A in oak-hickory forests of the Ohio Hill Country, by decade to 2020[a]

| Decade | Inventory, beginning of decade | Removals during decade | Value of inventory, beginning of decade[b] | Value of removals during decade[b] |
|---|---|---|---|---|
| | *Thousand cords* | | *Thousand dollars* | |
| 1970-1979 | 31,203 | 7,810 | 268,728 | 68,757 |
| 1980-1989 | 34,588 | 6,648 | 295,169 | 59,056 |
| 1990-1999 | 41,821 | 7,144 | 349,389 | 63,538 |
| 2000-2009 | 48,205 | 6,964 | 412,530 | 59,402 |
| 2010-2019 | 51,953 | 10,643 | 482,787 | 140,340 |
| 2020 | 51,861 | | 488,323 | — |

[a]386,700 acres in 9 opportunity classes (No. 4-9, 25, 28, and 29) receive intensive management. Current management practices continue on the remaining forest land.

[b]Assuming no change in the relative value of timber.

Table 5.—Projected results of implementing program B in oak-hickory forests of the Ohio Hill Country, by decade to 2020[a]

| Decade | Inventory, beginning of decade | Removals during decade | Value of inventory, beginning of decade[b] | Value of removals during decade[b] |
|---|---|---|---|---|
| | *Thousand cords* | | *Thousand dollars* | |
| 1970-1979 | 31,203 | 7,702 | 268,728 | 56,865 |
| 1980-1989 | 33,727 | 6,419 | 386,617 | 64,367 |
| 1990-1999 | 41,824 | 6,819 | 597,239 | 93,337 |
| 2000-2009 | 49,557 | 9,689 | 912,457 | 193,022 |
| 2010-2019 | 50,775 | 14,590 | 1,255,102 | 547,635 |
| 2020 | 46,236 | — | 1,371,368 | — |

[a]860,700 acres in 18 opportunity classes (No. 2-9, 23-25, 28-30, 32, 33, 35, and 36) receive intensive management. Current management practices continue on the remaining forest land.

[b]Assuming that timber values increase at compound rate of 2 percent.

Table 6.—Projected results of continuation of current management practices in oak-hickory forests of the Ohio Hill Country, by decade to 2020[a]

| Decade | Inventory, beginning of decade | Removals during decade | Value of Inventory, beginning of decade | Value of removals during decade |
|---|---|---|---|---|
| | *Thousand cords* | | *Thousand dollars* | |
| 1970-1979 | 31,203 | 7,109 | 268,728[b]<br>268,728[c] | 65,353[b]<br>71,568[c] |
| 1980-1989 | 34,419 | 7,109 | 278,451<br>339,425 | 65,353<br>87,252 |
| 1990-1999 | 40,863 | 7,109 | 316,700<br>470,590 | 65,353<br>106,354 |
| 2000-2009 | 46,137 | 7,109 | 342,337<br>620,100 | 65,353<br>129,629 |
| 2010-2019 | 53,796 | 7,109 | 356,417<br>786,992 | 65,353<br>158,018 |
| 2020 | 54,209 | — | 365,199<br>982,960 | —<br>— |

[a]No acreage receives intensive management; current management practices continue on all forest land.

[b]Assuming no change in the relative value of timber.

[c]Assuming that timber values increase at compound rate of 2 percent.

Table 7.—Potential effect of programs A and B in oak-hickory forests of the Ohio Hill Country, 1970-2020[a]

| Program | Area treated | Treatment costs | Increase in yield | | Increase in yield value | |
|---|---|---|---|---|---|---|
| | *Thousand acres* | *Million dollars* | *Million cords* | *Percent* | *Million dollars* | *Percent* |
| A | 386.7 | 10.7 | 1.3 | 2.3 | 187.5 | 44.3 |
| B | 860.7 | 24.9 | 1.7 | 2.9 | 790.8 | 62.4 |

[a]Relative timber value and treatment costs remain unchanged in program A and increase at a compound rate of 2 percent in program B.

a compound rate of 2 percent. A number of potential management opportunities were identified, but only those capable of yielding a positive present net worth at a 5-percent discount rate were considered worthy of program inclusion.

The potentials of programs A and B were evaluated by comparing the expected yields and yield values of each program with those resulting from a continuation of current management practices.

Program A would apply intensive management practices to 386,700 acres of oak-hickory forest in the Ohio Hill Country (table 7). The cost of treating these acres would be about $10.7 million. Timber yields over the next 50 years would be increased about 1.3 million cords; a net gain of 2.3 percent over the yields expected from a continuation of current management practices. The net gain in yield value would be approximately $187.5 million or 44.3 percent. This, of course, presumes perfect markets for added yields at given timber values.

For program B, intensive management practices would be carried out on 860,700 acres. Treatment costs would be $24.9 million. Timber yields would increase 1.7 million cords; a

net gain of 2.9 percent. And the net gain in yield value would be $790.8 million or 62.4 percent.

Neither program A or B would produce large increases in timber yield. But the expected gains in yield value are impressive. Gains in timber yield values would average $18 and $32 per management dollar spent in programs A and B, respectively. These results demonstrate the extent to which sound silviculture could improve timber quality and yield values in oak-hickory forests.

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# EMPIRICAL METHODS in the EVALUATION of ESTIMATORS

A case study based on insect density and survival data

by Gerald S. Walton
and C. J. DeMars

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6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE DIRECTOR

## The Authors

GERALD S. WALTON has served as a mathematical statistician in the biometrics branch of the Northeastern Forest Experiment Station since 1969. He received a bachelor of arts degree in mathematics from the University of California at Berkeley in 1960 and a master's degree in forest science from Harvard University in 1965.

C. J. DeMARS, a research entomologist, has been engaged in the study of bark beetles at the Pacific Southwest Forest and Range Experiment Station since 1957. He received a bachelor of science degree in forest science at the University of Georgia in 1953 and a Ph.D. degree in entomology at the University of California at Berkeley in 1966.

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# EMPIRICAL METHODS in the EVALUATION of ESTIMATORS

A case study based on insect density and survival data


## ABSTRACT

The authors discuss the problem of selecting estimators of density and survival by making use of data on a forest-defoliating larva, the spruce budworm. Various estimators are compared. The results show that, among the estimators considered, ratio-type estimators are superior in terms of bias and variance. The methods used in making comparisons, particularly simulation, are generally applicable to situations in which data appropriate for making estimates are on hand.


THE EFFICIENCY of estimates of population parameters is affected by the choices of both sampling plan and estimators. When a population parameter to be estimated is the mean of some variable, there is generally a best estimator for a given well-defined sampling method. It is then possible to compare different sampling methods in terms of the precision with which the best estimator for each sampling method estimates the population parameter of interest. However, when the population parameter to be estimated is not a weighted sum, over the population, of a variable, there will be a "best" estimator only under very restrictive assumptions about the population—assumptions that, in practice, cannot be readily verified.

In this paper, we are concerned with the estimation of density and survival in a population of forest-defoliating larvae under simple sampling methods. Generally "best" estimators do not exist for these parameters, so our investigations, of necessity, are pragmatic. We have used actual data for the spruce budworm (*Choristoneura occidentalis* Freeman).

We have also tried, in an informal way, to see why the better estimators performed as they did, so the results described might be generalized to some extent. And we hope the reader will find the methods we have used for comparing estimators, using a particular data base, of value. Certainly it is demonstrated that the choice of estimators is a matter of some consequence. The best estimators of survival and density were always at least 60 percent more efficient than the next best estimator for the data and sampling designs used in this study.

The selection of estimators for comparison would seem to be a straightforward problem. There are methods, such as maximum likelihood and minimum square error, which gener-

ally produce reasonably good estimators. The rub is that the joint distribution of the random variables involved must be known, if not to obtain good estimators to begin with, then to determine the bias and variance of any estimator.

## THE PROBLEM

Look at the example. A number of trees are randomly selected from a presumably infinite population of trees. From each tree, on each of two sampling dates, a fixed number of branches are randomly selected from the presumably infinite number of branches on the tree. Two random variables are measured: the number of insects on the branch and the branch surface area. These random variables will be written

$Y_{tij}$ for the number of insects

$X_{tij}$ for the branch surface area

where $t = 1, 2$ denotes the first or second sampling date; $i = 1, \ldots, n$ denotes the $i^{th}$ tree in the sample and $j = 1, \ldots, n_t$ denotes the number of the branch removed on sampling date t. The same trees are sampled at each date.

Our object is to estimate survival and density. But before we proceed, we must be specific in our definitions of these parameters. Clearly, the way in which the parameters are defined will affect the choice of estimators. Morris *(1955)* discussed the biological interpretation of certain insect population parameters. In our paper, we choose to define the density parameter at sampling period t by

$$D_t = Y_{t\cdot\cdot}/X_{t\cdot\cdot}$$

Y represents insects; and X, the branch surface area, is the product of the foliated branch length and greatest branch width. The dots denote sums over branches and trees in the population. Survival between time periods 1 and 2 is defined in terms of density, using the equation

$$S = D_2/D_1$$

At this point we inject a brief digression on the notational conventions peculiar to this paper. We will ignore the distinction between the true and measured values of the random variables X and Y, since they are presumed to be measured without error. A dot in place of a subscript denotes summation of the variable over that subscript. The standard $\Sigma$ operator will be used for more complex sums. The ranges of summations are denoted explicitly only when these are not clear from the context. That is, sums used in defining population parameters are taken over the whole population while sums used in defining estimates are taken over a sample from the population. We have dispensed with formal limiting procedures when dealing with functions of sums over infinite populations (e.g., $D_t$). Population parameters are represented by uppercase letters (S,D), while the corresponding estimators use lowercase letters (s,d). We differentiate between different estimators of the same population parameter by the use of uppercase subscripts ($s_M$,$s_R$). "t" always stands for sampling period. It is inevitable, since we will be discussing several estimators of the same parameter, that the reader will have trouble keeping the various estimators straight. In order to rectify this problem, all estimators are assembled in appendix III for ready reference. We return to the main theme of this paper by considering some implications of the definitions of population density and survival.

A common alternative to $D_t$ as a definition of the population density is

$$D_t^* = (1/N_t) \sum_{ij} (Y_{tij}/X_{tij})$$

for a finite population with $N_t$. total branches.

Our preference for $D_t$ is based on the intuitive feeling that insect density should not change if the number of insects and total branch surface area is the same at both sampling periods. If, in such a situation, the insects migrate to branches with greater surface area, $D_t^*$ decreases, while $D_t$ remains constant. Since $D_t^*$ can be affected by the spacial distribution of the insects, we elect to estimate $D_t$.

The survival parameter, S, as defined, is not the number of survivors divided by the number of insects initially present, although it does reduce to this if branch surface area is unchanged between sampling dates. Rather, S might be termed "survival relative to branch

surface area." The remainder of the paper is devoted to the estimation of S and $D_t$, to the exclusion of other population parameters.

## TRIAL COMPARISON OF SOME ESTIMATORS

One method of comparing estimators is simply to use each one on an appropriate set of data and observe the results. We have two examples of this in table 1. These examples are based on part of the data on spruce budworm collected in Montana in 1965 by the Insecticide Evaluation Project of the Pacific Southwest Forest and Range Experiment Station, USDA Forest Service (*Williams and Walton 1968*). The data are from two crown levels of 32 trees. Two branches were taken from each level at the two sampling dates.

The estimates in table 1 were computed as follows. The mean density was calculated, using

$$d_{Mt} = 1/(n\, n_t) \sum_{i,j} (Y_{tij} / X_{tij})$$

and the mean survival, using

$$s_M = 1/n \sum_i ( (Y_{2i.} / X_{2i.}) / (Y_{1i.} / X_{1i.}) ).$$

The ratio estimates of survival and density were got by

$$d_{Rt} = Y_{t..} / X_{t..} \text{ and}$$

$$s_R = \sum_i (Y_{2i.} X_{1i.}) / \sum_i (Y_{1i.} X_{2i.}).$$

Properties of the estimator $s_R$ are discussed in appendix I.

Density estimates were obtained from transformations of the form $\log (Y_{tij} / X_{tij} + k)$. One estimate, $d_{Lt}$, is the antilog of the sample mean of the transformed variables. The other estimate, $d_{Ft}$, is based on a method attributable to Finney (*1941*). This method gives unbiased estimates of the untransformed population mean if the transformed data are independent and normally distributed. Survival estimates based on the transformation

$$\log [(Y_{2i.} X_{1i.}) / (Y_{1i.} X_{2i.}) + k]$$

were also obtained using antilogs ($s_L$) and Finney's method ($s_F$).

The estimates in table 1 show a tendency to decrease, from left to right, in each row. The only exception is in the results for the lower crown, where $s_M$ and $s_R$ are in reverse order. The ordering implies that the estimates have different expectations or, in other words, that they are unbiased estimates of different population parameters. It is also evident that the constant, k, in the log-transformation has a pronounced effect on the estimates, especially at low densities. Since the population parame-

Table 1.—Estimates of density[1] and survival, and standard errors[2] for different estimators on the same data

| Item | Mean | Ratio | Logarithmic transformation | | | |
|---|---|---|---|---|---|---|
| | | | K = 1.0 | | K = .01 | |
| | | | F | L | F | L |
| | | LOWER CROWN | | | | |
| Density (1st date) | 2.555 | 2.541 | 1.988 | 1.926 | 1.281 | 1.049 |
| | ±.327 | ±.339 | ±.308 | ±.298 | ±.364 | ±.298 |
| Density (2nd date) | .311 | .267 | .215 | .205 | .029 | .022 |
| | ±.121 | ±.089 | ±.078 | ±.074 | ±.012 | ±.009 |
| Percent survival | 10.618 | 12.538 | 2.330 | 1.840 | .260 | .108 |
| | ±3.508 | ±4.056 | ±.862 | ±.681 | ±.105 | ±.044 |
| | | UPPER CROWN | | | | |
| Density (1st date) | 5.434 | 4.994 | 4.191 | 4.060 | 3.730 | 3.494 |
| | ±.784 | ±.718 | ±.587 | ±.569 | ±.658 | ±.616 |
| Density (2nd date) | .674 | .579 | .430 | .411 | .076 | .056 |
| | ±.203 | ±.169 | ±.118 | ±.113 | ±.027 | ±.020 |
| Percent survival | 19.526 | 12.891 | 4.554 | 3.652 | 1.217 | .498 |
| | ±7.515 | ±4.291 | ±1.501 | ±1.204 | ±.475 | ±.194 |

[1]Density is expressed in insects per 100 square inches of branch surface area.
[2]The standard error of estimate is shown below the estimate.

ters are unknown, it is impossible to draw any conclusion about the degree of bias of any of the estimators.

The standard errors for the mean and ratio estimates in table 1 were estimated by conventional formulas, and those for the ratio estimates by using the combined ratio formulae (*Cochran 1953*, section 6.11) treating each tree as a strata with the same (large) number of branches. The errors for the log-transformation estimates were estimated on the assumption that the transformed data are normally distributed, as indicated by Finney. The resulting estimates are not valid unless the normality assumption is true. The data were roughly "normal" for $k = 1.0$, but very skew for $k = .01$. Comparison of the coefficients of variation of the estimates gives no evidence that any particular estimator is superior by this criterion. However, because of the notoriously high variability of error estimates and the small number of data sets considered, no firm conclusion can be drawn from this comparison.

## THEORETICAL PROPERTIES OF ESTIMATORS

A more orderly procedure is to consider the conditions under which an estimator is optimal in some sense and to discard those estimators for which the optimum conditions are obviously not met by the data. For instance, the sample mean is an unbiased estimate of the population mean under random sampling. Now, the population means of $Y_{tij}/X_{tij}$ and $(Y_{2i.}/X_{2i.})\ /\ (Y_{1i.}/X_{1i.})$ are not population density ($D_t$) and survival (S). Therefore, $d_{Mt}$ and $s_M$ are biased estimators of $D_t$ and S. A sample mean is a minimum variance estimator of the population mean if the sample mean and its variance are independent. This condition was not met by the data in table 1, so $d_{Mt}$ and $s_M$ are probably not minimum variance estimators.

From scatter diagrams, based on trees, the variances of both $Y_{tij}/X_{tij}$ and $(Y_{2i.}/X_{2i.})\ /\ (Y_{1i.}/X_{1i.})$ appeared to be roughly proportional to the square of their means. In this case, a transformation of the form

$$\log (Z + k)$$

tends to induce independence between mean and variance on the transformed scale. k is needed to ensure the existence of the transform when $Z = 0$, and affects the resulting distribution. Anscombe [1949] discusses selection of values for k. If the transformation does result in independence of mean and variance on the transformed scale, the mean on the transformed scale would be the minimum-variance linear estimator of the population mean of the transformed variables. One would expect estimates on the untransformed scale which were based on the mean of the transformed data to be low variance estimators. The antilog of the mean of the log-transformed data estimates the geometric mean of $(Z+k)$. The estimates $d_{Lt}$ and $s_L$ were computed by subtracting k from the antilogs of the transformed means. Thus $d_{Lt}$ and $s_L$ should have reasonably small standard errors, but there is no reason why they should be unbiased estimates of $D_t$ and S.

Transformations that induce independence between mean and variance often tend to make the data more normally distributed. If the log-transformed data are in fact normal, Finney's method gives unbiased estimates of the population mean of the untransformed data. In this case, $d_{Ft}$ and $s_F$ have the same expectation as $d_{Mt}$ and $s_M$, so they are biased estimators of $D_t$ and S. The estimates $d_{Ft}$ and $s_F$ should have smaller variances than $d_{Mt}$ and $s_M$.

Scatter diagrams may not unambiguously indicate variance-mean relationships. For the data used in table 1, we could easily have argued that the variance of the mean for a tree was proportional to $\mu + \lambda^2 \mu^2$, where $\mu$ is the tree mean and $\lambda$ is a constant. Beall (*1942*) showed that this relation leads to the variance stabilization transformation $T(z) = \lambda^{-1} \sinh^{-1} (\lambda \sqrt{z})$ in the same way that the assumption that the variance is proportional to $\mu^2$ leads to the log-transformation we just considered. We therefore introduce two new estimators of $D_t$ and S, written $d_{tB}$ and $s_B$, based on the inverse of the transformation T applied to the mean of the T-transformed data. Neyman and Scott (1960) gave a method for obtaining unbiased estimators of

the mean on the untransformed scale when the transformed data are normally distributed. This method, which is analogous to Finney's method for the log transformation, led us to consider the estimators, $d_{Nt}$ and $s_N$, of $D_t$ and S. All the comments we have made about the estimators based on the log transformation are, by analogy, appropriate to the corresponding etsimators based on the T transformation.

The sample ratio, $d_{Rt} = Y_{t..}/X_{t..}$, is an unbiased estimator of $D_t$ if

$$Y_{tij} = D_t X_{tij} + e_{tij}$$

where the $e_{tij}$ are independent errors with zero expectations ($E(e_{tij}) = 0$) for any $X_{tij}$. We assume the $X_{tij}$ are known exactly and that $E(e_{tij}|X_{tij}) = 0$ within the sample. $d_{Rt}$ is an unbiased estimate of $D_t$ under weaker conditions, as shown in appendix I. Further, $d_{Rt}$ is a minimum variance estimator if $E(e^2_{tij}) = hX_{tij}$ for all $X_{tij}$ and some constant, h. The conditions for unbiasedness and minimum variance for ratio estimators are given in several texts, including Sukhatme (*1954, p. 154*) and Cochran (*1953, p. 123*). These conditions appeared to be satisfied by the test data.

In table 1, $s_R = (\Sigma Y_{2i.} X_{1i.}) / (\Sigma Y_{1i.} X_{2i.})$ was used to estimate survival. It should be noted that this is not the estimator $(Y_{2..} X_{1..}) / (Y_{1..} X_{2..})$. In appendix I, conditions under which $s_R$ is an unbiased estimate of the population survival, S, are shown. Roughly, the assumptions include:

- The conditions for $d_{Rt}$ to be an unbiased estimator hold for both sampling periods 1 and 2.
- The $X_{ti.}$ are independent random variables within any sampling period. (Note that for unbiased estimates of density, only the error terms were required to be independent. It need not even be assumed that branch surface area is a random variable.)
- Various assumptions about the independence of the random variables.

The mathematical conditions for $s_R$ to be minimum variance can be established. However, unlike the conditions for unbiasedness given above, they are too complex to be subject to biological interpretation.

Tin (1965) gave an adjustment to ratio estimators that reduces bias when the conditions for unbiasedness do not hold. The adjustment applied to the density estimator may, for infinite populations, be written

$$d_{At} = \frac{Y_{t..}}{X_{t..}} \left[ 1 - \frac{n}{n-1} \left\{ \frac{\Sigma X^2_{ti.}}{(\Sigma X_{ti.})^2} - \frac{\Sigma X_{ti.} Y_{ti.}}{(\Sigma X_{ti.})(\Sigma Y_{ti.})} \right\} \right]$$

The price paid for the reduction in bias is a higher variance, although generally not much higher than for $d_{Rt}$. $d_{At}$ was not included in table 1, but will be considered later.

Using a modification of Tin's approach, we obtained correction term for the "within–tree" bias for the estimator, $s_R$. For the $i^{th}$ tree, the resulting correction factor is

$$C_i = \left[ 1 - \frac{n_1}{n_1 - 1} \left\{ \frac{\Sigma Y^2_{1ij}}{(Y_{1i.})^2} - \frac{\Sigma X_{1ij} Y_{1ij}}{(X_{1i.})(Y_{1i.})} \right\} \right] \cdot \left[ 1 - \frac{n_2}{n_2 - 1} \left\{ \frac{\Sigma X^2_{2ij}}{(X_{2i.})^2} - \frac{\Sigma X_{2ij} Y_{2ij}}{(X_{2i.})(Y_{2i.})} \right\} \right]$$

If the variance of the correction term is independent of the random variables on the right side of the equation, the "corrected" estimate of S would best be got by $s_R(C./N)$. This condition was well satisfied by our test data.

In considering which of the estimators just discussed should be used, the ratio estimators appear to have the edge. Under certain conditions, the other estimators give unbiased estimates of population parameters other than density and survival as we have defined them. The ratio estimators are unbiased estimators of density and survival under ideal conditions. These conditions are fairly restrictive, so bias correction might be needed.

## INVESTIGATIONS BASED ON SIMULATION

In practice, one would not expect specific optimality conditions required for an estimator to hold precisely. Therefore, we have used Monte Carlo simulation in order to study the behavior of the estimators over a range of con-

ditions likely to be encountered in applications. To construct a simulator that generates realistic data, we considered diverse sets of budworm data and established characteristics which these sets had in common.

We concluded, in agreement with Morris *(1955)*, that the number of insects on a branch closely follows the negative binomial frequency distribution, regardless of the intensity of the populations we observed. Further, by plotting, we found that

$$\frac{Y_{tij} - D_t X_{tij}}{\sqrt{X_{tij}}}$$

was distributed roughly normally for these populations. These conditions were used to define the joint distribution of insects and branch surface area, given the means, variances, and covariance of these variables at one sampling date (appendix II).

A computer program was written that generated simulated insect counts and branch surface areas. The computer was supplied the means, variances, and covariance of X and Y at each sampling date. To study the properties of the estimators on an individual tree basis, the same characteristics were used for 500 independent tree samplings with 4 branches sampled at the first period, 8 at the second.

The results of these simulations for the ratio estimators are given in table 2. From this table we concluded that the ratio is serviceable as an estimator of population density. For survival estimates, the bias-corrected ratio estimator, $s_A$, should be used.

The mean and uncorrected transform based estimates were all high. Both bias and variance were reduced by corrections to these estimates, but the corrections were too great for low density or low survival rates, and too small for high density or survival. The square

Table 2.—The tree mean, standard error, and bias of the ratio estimators, estimated by simulation

| Case[1] | True parameter | Average estimate | Standard error of tree estimate | Estimate of bias | t-test for bias = 0 |
|---|---|---|---|---|---|
| DENSITY IN INSECTS PER 1,000 SQUARE INCHES OF FOLIAGE | | | | | |
| 1 | 44.064 | [2]46.288 | 16.422 | 2.224 | 3.03 |
| | | 44.762 | 14.450 | .698 | 1.08 |
| 2 | 33.256 | 33.405 | 12.661 | .149 | .26 |
| | | 32.633 | 11.905 | —.623 | —1.17 |
| 3 | 28.091 | 28.932 | 26.593 | .840 | .72 |
| | | 24.627 | 27.521 | —3.464 | —2.82 |
| 4 | 22.485 | 24.543 | 23.850 | 2.058 | 1.93 |
| | | 18.049 | 41.808 | —4.436 | —2.37 |
| 5 | 11.877 | 12.005 | 8.074 | .127 | .35 |
| | | 11.634 | 7.513 | —.243 | —.72 |
| 6 | 5.706 | 5.635 | 3.632 | —.071 | —.44 |
| | | 5.537 | 3.494 | —.170 | —1.09 |
| 7 | 2.480 | 2.476 | 2.114 | —.403 | —.04 |
| | | 2.433 | 2.036 | —.047 | —.52 |
| 8 | 1.363 | 1.342 | 1.458 | —.021 | —.32 |
| | | 1.319 | 1.409 | —.044 | —.69 |
| PERCENT SURVIVAL | | | | | |
| 1-8 | 3.093 | 3.254 | 3.833 | 0.161 | 0.04 |
| | | 2.915 | 3.466 | —.178 | —1.15 |
| 2-7 | 7.458 | 8.653 | 8.671 | 1.195 | 3.08 |
| | | 7.319 | 7.011 | —.139 | —.44 |
| 3-6 | 20.314 | 45.170 | 77.837 | 24.856 | 7.15 |
| | | 17.420 | 24.068 | —2.894 | —2.69 |
| 4-5 | 52.822 | 116.787 | 210.391 | 63.965 | 6.80 |
| | | 49.715 | 82.832 | —3.107 | —.84 |

[1]Cases 1 to 4 are based on 4 branch samples per tree, cases 5 to 8 on 8 branch samples. 500 trees were sampled for each case.

[2]For each case, the first row is not corrected for bias, while the second row is.

of the coefficient of variation of all but the mean estimators is roughly in inverse proportion to the sample size. Thus a measure of efficiency, which approximates the ratio of sample sizes required for equal coefficients of variation, is the square of the ratio of coefficients of variation. With this measure of efficiency, one of the ratio estimates is always at least 60 percent more efficient than any transform based estimator of the same parameter. We have given detailed results only on the ratio estimators and their vaiances, since none of the other estimators are serious competitors.

However, data are generally transformed to induce independence of mean and variance and, one hopes, to make the data more normally distributed, in order to satisfy assumptions required in analysis of variance. Two rough measures of normality are skew ($\gamma_1$) and kurtosis ($\gamma_2$). Both are zero for normal distributions. They are defined, for a random variable Z, by

$$\gamma_1 = E(Z\text{-}E(Z))^3 / [E(Z\text{-}E(Z))^2]^{3/2} \text{ and}$$

$$\gamma_2 = E(Z\text{-}E(Z))^4 / [E(Z\text{-}E(Z))^2] - 3.$$

Table 3 gives estimates of the skew and kurtosis of the means of the transformed data on each tree.

The skew and kurtosis are of an order such that the transformed variables would ordinarily be considered normally distributed in practice. Scheffé *(1959, p. 333)* gives values of $\gamma_1$ and $\gamma_2$ typically occurring in applications. From table 3, there is no clear difference between the log and Beall's transformation. Beall's transformation appears to give the better results, but this might be because the constant $\lambda$ in the transformation was determined exactly from the parameters of the simulator. We did not check the sensitivity of the transformation to the choice of $\lambda$. The constant K in the log transformation was estimated from all 500 trees for each case, and so is much more adequately estimated than it would ordinarily be. Where 1 was added before taking logs, the results are still quite good, indicating the choice of a constant for the log transformation is not critical if reasonable care is taken to ensure normality.

It should be noted that the simulator was not constructed so that any of the above transformations would induce normality. However, these transformations have been known to do so with similar insect data (*Morris 1955*). The fact that the simulator reproduced this distribution property would certainly support the realism of the assumptions that were used in constructing the simulator.

In any interpretation of the simulation results, one should recognize that all of the 500 trees sampled in a simulation case had identically distributed insects and branch surface areas. Equivalently, each simulation case represents 500 independent samplings of the same tree. The results of the simulation indicate that the ratio estimators were very satisfactory when individual trees were treated as the population sampled. We cannot, however, on the basis of the simulation alone, extend the results of the simulation to groups of trees where the distribution of insects and trees are

**Table 3.—Estimates of skew and kurtosis of simulated data after transformation**

| Case[1] | Skewness | | | Kurtosis | | |
|---|---|---|---|---|---|---|
| | log(Y/X+1) | log(Y/X+K)[2] | Beall | log(Y/X+1) | log(Y/X+K)[2] | Beall |
| 1 | 0.138 | 0.569 | 0.438 | 0.941 | 1.423 | 1.310 |
| 2 | —.636 | .037 | —.327 | .946 | .574 | .783 |
| 3 | .088 | .020 | —.073 | —.317 | —.314 | —.336 |
| 4 | .067 | .066 | —.175 | —.175 | —.176 | —.210 |
| 5 | .286 | .279 | .169 | .258 | .249 | .130 |
| 6 | .510 | .555 | .436 | .583 | .724 | .380 |
| 7 | .667 | .650 | .595 | .342 | .290 | .149 |
| 8 | .755 | .700 | .667 | .111 | .002 | —.490 |

[1]For each case, the same data are used as for the corresponding case in Table 2.
[2]K was estimated from the simulated data.

not identical, since the behavior of the various estimators will be affected by the differences between trees.

## SUMMARY AND CONCLUSIONS

Our objective was to find estimators of well-defined population parameters for use on specific data. The behaviors of selected estimators were compared in three steps.

First, estimates were computed on sample data. From this step we concluded that there were important differences between estimators, but we were unable to decide which estimators were better in any sense.

In the second step, we checked to see what optimality criteria might be roughly satisfied by the data. The results concerning variance stabilizing transformations were inconclusive. However, the data did conform reasonably well to the conditions for unbiasedness and minimum variance for the ratio estimators.

In the third step, simulation was used to appraise the influence of departures from ideal conditions on the ratio estimators. Bias, which was our major concern, is generally most apparent in small samples for ratio estimators. We therefore sampled a single tree many times, using the simulator. The distributional characteristics of the simulated data were based on the corresponding characteristics of actual data. In addition to information on the behavior of the ratio estimators under diverse conditions, the simulator gave us insight on the effectiveness of variance stabilization transformations in "normalizing" the data, and the sensitivity of these transformations to the choice of constants.

Variations on the steps given in the preceding paragraphs would be applicable to the problem of selecting an estimator of any population parameter from an adequate data base. For the specific problem we considered, that of estimating insect density ($D_t$) and survival ($S$), we came to the following conclusions.

The ratio estimators ($d_{Rt}$, $d_{At}$, $s_R$ and $s_A$) were superior to the other estimators considered in terms of bias, as established by individual tree simulation. In these simulations, the ratio estimators were always at least 60 percent more efficient than the other estimators. For estimating survival, there is a slight advantage in using the bias-adjusted estimator, $s_A$. For estimating density, the unadjusted ratio estimator, $d_{Rt}$, seems adequate. These results from simulation, plus the correspondence of observed data to the conditions required for optimality of the ratio estimators, leads us to conclude that $d_{Rt}$ and $s_R$ should be used to estimate $D_t$ and $S$.

Estimates of skew and kurtosis of the ratio estimators based on simulation indicate these estimators are far from normally distributed on an individual tree basis. Therefore, for hypothesis testing within an analysis of variance framework, we recommend using either log or $\sinh^{-1}$ transformations to "normalize" the data. The skew and kurtosis of either transformation was fairly insensitive to small changes in the constants involved in the transformations. Moderate care in setting these constants should suffice in practice.

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# APPENDIX I

## Conditions for Unbiasedness of the Double Ratio Estimator

The object of this appendix is to present a set of conditions under which the estimator $s_R$ yields unbiased estimates of S. The conditions imposed cannot be expected to hold exactly in practice. The utility of this demonstration will be as a guide to conditions that must be approximately satisfied if $s_R$ is to be trusted as an estimate of S. And $s_R$ may be unbiased under other, and perhaps less stringent, conditions.

The conditions are labeled with roman numerals for easy reference. The conditions are stated as they are used in the demonstration partly because this makes it easier to see how the demonstration turns on the assumptions, partly because the conditions are more comprehensible at that point in the development, and partly to emphasize that the conditions are imposed in order to procede with the demonstration.

To begin, we write the number of insects on the $j^{th}$ branch of the $i^{th}$ tree at time t as

$$Y_{tij}=D_tX_{tij}.e_{tij}$$

If the sampling of the branches on the $i^{th}$ tree at time t is such that $E(e_{tij})=0$ then, summing over the branch samples, we have

$$Y_{ti.}=D_tX_{ti.}+e_{ti.} \text{ and } E(e_{ti.})=0.$$

If the N trees are sampled independently, the $e_{ti.}$ will be independent between trees for fixed t. With this motivation we state the following conditions, which are sufficient for $d_{tR}$ to be an unbiased estimator of $D_t$, namely:

(I) $Y_{ti.}=D_tX_{ti.}+e_{ti.}, E(e_{ti.})=0$ and $e_{ti}$ is independent of $e_{tj}$ for $i \neq j$.

The estimator $s_R$ has been defined as

(2) $s_R=(\Sigma Y_{2i}X_{1i})/\Sigma(Y_{1i}X_{2i})=\Sigma Y_i^*/\Sigma X_i^*$

where

(3) $Y_i^*=Y_{2i}.X_{1i}.$ and $X_i^*=Y_{1i}.X_{2i}$

Define the population parameter $S^*$ by

(4) $S^*=(\Sigma Y_{2i}.X_{1i}.)/(\Sigma Y_{1i}.X_{2i}.)$

and $e_i^*$ by the relation

(5) $Y_i^*=S^*X_i^*+e_i^*$

We will first establish conditions under which $E(e_i^*)=0$ and the $e_i^*$ are independent, which is tantamount to showing $s_R$ is an unbiased estimate of $S^*$. Then we will establish conditions under which $S^*=S$, where

(6) $S=(\Sigma Y_{2i})(\Sigma X_{1i})/(\Sigma Y_{1i})(\Sigma X_{2i})=D_2/D_1$

Using (I), (2), (3), (4) and (5) we may write

$e_i^*=Y_i^*-S^*X_i^*=Y_{2i}.X_{1i}-(D_2/D_1)Y_{1i}.X_{2i}$

$=(D_2X_{2i}+e_{2i})X_{1i}-(D_2/D_1)(D_1X_{1i}+e_{1i})X_{2i}$

$=e_{2i}.X_{1i}.-(D_2/D_1)e_{1i}.X_{2i}.$ or

(7) $e_i^*=(D_1e_{2i}.X_{1i}-D_2e_{1i}X_{2i})/D_1$

From (7),

$$(8)\quad E(e_i^*) = (D_1E(e_{2i}X_{1i}) - D_2E(e_{1i}X_{2i})) / D_1$$

We impose the condition that the "tree error" at one sampling date is not correlated with the total branch surface area from the same tree at the other sampling date. Formally,

$$(IX)\quad E(e_{ti}X_{si}) = E(e_{ti})E(X_{si}) \text{ for } t \neq s.$$

Then since $E(e_{ti}) = 0$ from (I), $E(e_i^*) = 0$, which is what we set out to show.

We will now establish additional conditions so $E(e_i^* e_j^*) = E(e_i^*)E(e_j^*)$ for $i \neq j$. From (7),

$$\begin{aligned} E(e_i^* e_j^*) = E \Big[ & (D_1X_{1i}e_{2i} - D_2X_{2i}e_{1i}) / D_1 \\ & (D_1X_{1j}e_{2j} - D_2X_{2j}e_{1j}) / D_1 \Big] \\ = E \Big[ & D_1^2X_{1i}e_{2i}X_{1j}e_{2j} \\ & - D_1D_2X_{1i}e_{2i}X_{2j}e_{1j} \\ & - D_1D_2X_{2i}e_{1i}X_{1j}e_{2j} \\ & + D_2^2X_{2i}e_{1i}X_{2j}e_{1j} \Big] / D_1^2 \end{aligned}$$

Now, from (8),

$$\begin{aligned} E(e_i^*)E(e_j^*) = & D_1^2E(X_{1i}e_{2i})E(X_{1j}e_{2j}) \\ & - D_1D_2E(X_{1i}e_{2i})E(X_{2j}e_{1j}) \\ & - D_1D_2E(X_{2i}e_{1i})E(X_{1j}e_{2j}) \\ & + D_2^2E(X_{2i}e_{1i})E(X_{2j}e_{1j}) \quad D_1^2 \end{aligned}$$

It is apparent that the last two equations are equivalent if

$$(X)\quad E(X_{1i}e_{2i}X_{1j}e_{2j}) = E(X_{1i}e_{2i})E(X_{1j}e_{2j})$$

$$E(X_{1i}e_{2i}X_{2j}e_{1j}) = E(X_{1i}e_{2i})E(X_{2j}e_{1j})$$

$$E(X_{2i}e_{1i}X_{1j}e_{2j}) = E(X_{2i}e_{1i})E(X_{1j}e_{2j})$$

$$E(X_{2i}e_{1i}X_{2j}e_{1j}) = E(X_{2i}e_{1i})E(X_{2j}e_{1j})$$

for $i \neq j$.

In words, the above assumption is that the product of the branch surface area for a tree at one sampling date and "tree error" at the other sampling date are uncorrelated between different trees, and it allowed us to show $E(e_i^* e_j) = E(e_i^*)E(e_j^*)$ for $i \neq j$. That is, $e_i^*$ and $e_i^*$ are uncorrelated.

Showing two variables are independent is sufficient to show they are uncorrelated. Showing two variables are uncorrelated is not sufficient to prove they are independent although it certainly makes independence a more palatable assumption. For $s_R$ to be an unbiased estimator of $S^*$, we need independence, and therefore must make independence an assumption:

(XI) $e_i^*$ and $e_j^*$ are independent for $i \neq j$.

We still have to justify our claim S and $S^*$ are the same population parameter, where $S^* = (\Sigma Y_{2i}X_{1i}) / (\Sigma Y_{1i}X_{2i})$ and S is as shown in (6).

Up to this point in this appendix we have made no conditions on the number of trees or branches.

Let there be a finite population of, say, $i = 1, M$ trees such that $Y_{ti} = D_t X_{ti} + e_{ti}$. Write

$$S_M^* = \left(\sum_{i=1}^{M} Y_{2i} X_{1i}\right) / \left(\sum_{i=1}^{M} Y_{1i} X_{2i}\right)$$

$$= \frac{D_2 \Sigma (X_{2i} + e_{2i}/D_2)/X_{1i}}{D_1 \Sigma (X_{1i} + e_{1i}/D_1)/X_{2i}}$$

$$= \frac{D_2}{D_1} \left[\frac{(\Sigma X_{1i} X_{2i}) + (\Sigma X_{1i} e_{2i}/D_2)}{(\Sigma X_{1i} X_{2i}) + (\Sigma X_{2i} e_{1i}/D_1)}\right]$$

$$(12) \quad S_M^* = \frac{D_2}{D_1} \left[1 + \frac{(\Sigma e_{2i} X_{1i}/D_2)/M}{(\Sigma X_{1i} X_{2i})/M} - \frac{(\Sigma e_{1i} X_{2i} D_1)/M}{+ (\Sigma X_{2i} e_{1i}/D_2)/M}\right]$$

We write $\mu_M(Z_i)$ for $\Sigma Z_i/M$, since this is the mean of the M- population. We assume that the M-population can be augmented indefinitely so that in the limit as $M \to \infty$ , $\mu_M(e_{ti}) = 0$ for all $X_{ti}$ as implied by (I), and $\mu_M(X_{ti} e_{sj}) = \mu_M(X_{ti})\, \mu_M(e_{sj})$ for $i \neq j$ and $s \neq t$, as implied by (3). Since $X_{1i}$ and $X_{2i} > 0$, we have, from (12),

$$\lim_{M \to \infty} S_M^* = S^* = \frac{D_2}{D_1} = S.$$

It should be proven that such a limiting process exists for any infinite population meeting conditions [I], [IX], and (XI). The proof is beyond the scope of the authors.

# APPENDIX II

## Discussion of the Simulation Model Used in Generating Insect Counts and Branch Surface Areas

We start with the assumption that the insect counts ($Y$) follow the negative binomial distribution, and that the population means, variances, and covariance for the branch surface area ($X$) and insect counts are known. Because the mean and variance of a negative binomial variable completely determine its distribution, the $Y_i$ are easily generated using a psuedo-random number generator for the rectangular distribution.

We also want $(Y_i - dX_i) / \sqrt{X_i}$ to be roughly normally distributed. Since $Y_i$ is determined by its mean and variance, and $X_i$ appears twice, it is inconvenient to have the statistic exactly normally distributed. However, because $Y_i \doteq dX_i$, we chose to consider the statistic $(X_i - CY_i) / \sqrt{Y_i}$ in place of the former. This statistic is not entirely satisfactory either, because $P[Y_i = 0] \neq 0$.
Consequently, we add the $R(0,1)$ variable $r_i$ to $Y_i$. But, branch surface area may never be negative or zero so a constant $K$ is introduced to reduce $P[X_i \leq 0]$ to nearly zero for all $Y_i$.

The final model selected is

$$(1) \quad [(X_i - K) - C(Y_i + r_i)] \quad \sqrt{\sigma(Y_i + r_i)} = e_i$$

where $e_i \sim N(0,1)$, $r_i \sim R(0,1)$ and $Y_i \sim N.B.(\mu_Y, V_Y)$ and all three variables are independently distributed.

Once $e_i, r_i$ and $Y_i$ are generated by the pseudo-random number generator it can be seen from (1) that $X_i$ is determined by the equation

$$(2) \quad X_i = K + C(Y_i + r_i) + \sigma e_i (Y_i + r_i)^{1/2}.$$

We must now demonstrate that the constants $K$, $\sigma$, and $C$ are uniquely determined by the population means ($\mu_Y$ and $\mu_X$) variances ($V_Y$ and $V_X$) and covariance $Cov(X,Y)$.
From (2),

$$(3) \quad \mu_X = E(X_i) = K + C(\mu_Y + 1/2) \text{ and}$$

$$\begin{aligned} E(X_i^2) = E\Big[ & K^2 + \sigma^2 e_i^2 (Y + r_i) + C^2(Y_i^2 + 2Y_i r_i + r_i^2) \\ & + 2KC(Y_i + r_i) + \sigma e_i (Y_i + r_i)^{1/2} (K + C(Y_i + r_i)) \Big] \\ = {} & K^2 + \sigma^2(\mu_Y + 1/2) + C^2(V_Y + \mu_Y^2 + \mu_Y + 1/3) \\ & + 2KC(\mu_Y + 1/2) \end{aligned}$$

so, $V(X) = E(X_i^2) - E^2(X_i)$

$$(4) \quad V(X) = \sigma^2(\mu_Y + 1/2) + C^2(V_Y + 1/12)$$

For $Cov(X,Y)$ we compute, using (2),

$$\begin{aligned} E(X_i, Y_i) &= E\left[ KY_i + C(Y_i^2 + Y_i r_i) + \sigma e_i (Y_i + r_i)^{1/2} Y_i \right] \\ &= K\mu_Y + C(V_Y + \mu_Y^2 + \mu_Y/2), \end{aligned}$$

since $E(e_i) = 0$ independently of $Y_i$ and $r_i$.

But then

$$\begin{aligned}\mathrm{Cov}(X,Y) &= E(X_1Y_1) - E(X_1)\,E(Y_1)\\ &= K\mu_y + C(V_y + \mu_y^2 + \mu_y/2)\\ &\quad - K\mu_y - C(\mu_y^2 + \mu_y/2)\end{aligned}$$

$$(5)\quad \mathrm{Cov}(X,Y) = CV_y$$

It can easily be seen that the constants C, $\sigma$ and K are uniquely determined. C can be got from (5). Given C, $\sigma$ is available from (4), and then K can be found using (3).

# APPENDIX III

## Summary of Estimators

1. The "mean" estimators were defined by

$$d_{Mt} = 1/(nn_t) \sum_{i,j} (Y_{tij}/X_{tij}) \text{ and}$$

$$s_M = 1/n \sum \left[ (Y_{2i}/X_{2i}) / (Y_{1i}/X_{1i}) \right]$$

2. The simple ratio estimators are

$$d_{Rt} = Y_t / X_t \text{ and}$$

$$s_R = \left[ \sum_i (Y_{2i} X_{1i}) \right] / \left[ \sum_i (Y_{1i} X_{2i}) \right]$$

3. Adjusting the simple ratio estimate for bias leads to the adjusted ratio estimates

$$d_{At} = d_{Rt} \left[ 1 - \frac{n}{n-1} \left\{ \frac{\Sigma X^2_{tij}}{(\Sigma X_{tij})^2} - \frac{\Sigma X_{tij} Y_{tij}}{(\Sigma X_{tij})(\Sigma Y_{tij})} \right\} \right]$$

$$\text{and } s_A = s_R \left[ 1 - \frac{n_1}{n_1 - 1} \left\{ \frac{\Sigma Y^2_{1ij}}{(Y_{1i})^2} - \frac{\Sigma X_{1ij} Y_{1ij}}{(X_{1i} Y_{1i})} \right\} \right] \cdot$$

$$\left[ 1 - \frac{n_2}{n_2 - 1} \left\{ \frac{\Sigma X^2_{2ij}}{(X_{2i})^2} - \frac{\Sigma X_{2ij} Y_{2ij}}{(X_{2i} Y_{2i})} \right\} \right]$$

The equation for $s_A$ is appropriate in the above form for a single tree. See the discussion for clarification.

4. Earlier, estimators based on log-tranformations were introduced.

Let

$$\mu_{tij} = \log \left[ Y_{tij}/X_{tij} + K \right]$$

Then,

$$d_{Lt} = \exp \left[ \mu_t / nn_t \right] - K$$

Also, let

$$v_i = \log \left[ (Y_{2i}/X_{2i}) / (Y_{1i}/X_{1i}) + K \right] .$$

Then,

$$s_L = \exp \left[ v_i/n \right] - K$$

5. We presented estimators based on Finney's method of correcting for bias in estimators of the mean of log-normal populations.

Let

$$\bar{U}_t = U_{t\cdot}/nn_t \text{ and}$$

$$\hat{\sigma}^2_{\bar{U}t} = {}_1\Sigma_j (U_{tij} - \bar{U}_t)^2 / \left[(nn_t - 1)nn_t\right] .$$

Define

$$g(t) = 1 + \frac{n-1}{n} t + \frac{(n-1)^2 t^2}{2!n^2(n+1)} + \frac{(n-1)^3 t^3}{3!n^3(n+1)(n+2)} + \cdots$$

Then,

$$d_{Ft} = \exp(\bar{U}_t)\, g(\tfrac{1}{2} \hat{\sigma}^2_{\bar{U}t}) - K.$$

Similarly, let

$$\bar{V} = V_{\cdot}/n \text{ and } \hat{\sigma}^2_{\bar{V}} = \Sigma(\bar{V} - V_i)^2 / \left[n(n-1)\right] .$$

Then

$$s_F = \exp(\bar{V})\, g(\tfrac{1}{2} \hat{\sigma}^2_{\bar{V}})$$

6. Beall [1942] studied a transformation which we adapted for estimation.

Let

$$P_{tij} = \lambda^{-1} \sinh^{-1} \lambda\left(\sqrt{Y_{tij}/X_{tij}}\right)$$

Then,

$$d_{Bt} = \lambda^{-1} \sinh^2(\lambda P_{t\cdot}/nn_t).$$

Let

$$q_i = \lambda^{-1} \sinh^{-1} \lambda\left(\sqrt{(Y_{2i}/X_{2i})\ (Y_{1i}/X_{1i})}\right)$$

Then,

$$s_B = \lambda^{-1} \sinh^2(\lambda q_{\cdot}/n)$$

7. Neyman and Scott (1960) extended Finney's method for bias correction to other transformations. We introduced a "bias corrected" estimator based on this work for Beall's transformation. Let

$$\bar{P}_t = P_{t\cdot}/nn_t \text{ and } \hat{\sigma}^2_{\bar{P}t} = \frac{\Sigma\Sigma(\bar{P}_t - P_{tij})^2}{nn_t(nn_t - 1)} .$$

$$d_{Bt} = \frac{1}{2\lambda^2} \left[\cosh(2\lambda \bar{P}_t)\, g(2\lambda^2 \hat{\sigma}^2_{\bar{P}t}) - 1\right],$$

where $g(t)$ is given in part 5.

Also, let $\bar{q} = q_{\cdot}/n$, $\hat{\sigma}^2_{\bar{q}} = \dfrac{\Sigma(\bar{q} - q_i)^2}{n(n-1)}$

Then

$$s_B = \frac{1}{2\lambda^2} \left[\cosh(2\lambda \bar{q})\, g(2\lambda^2 \hat{\sigma}^2_{\bar{q}}) - 1\right] .$$

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# Factors Affecting the Use of Hardwood Flooring in Urban Rehabilitation

by Robert L. Nevel, Jr.

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Author

ROBERT L. NEVEL, JR. received his bachelor of science degree in forest technology from The Pennsylvania State University in 1965 and his master of forestry degree in wood technology from Yale University in 1968. He joined the staff of the Northeastern Forest Experiment Station at the Forest Products Marketing Laboratory, Princeton, West Virginia, in 1968. At the time this report was prepared, he was in charge of construction-oriented research on secondary manufactured wood products at that laboratory.

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# Factors Affecting the Use of Hardwood Flooring in Urban Rehabilitation


## ABSTRACT

The continued use of hardwood flooring in urban rehabilitation is being threatened. A study of the influences that determine the choice of flooring indicates that economic, physical, or technological factors dominate. Most factors affecting the use of hardwood flooring are related to cost, availability, and compatibility. Of these factors, time and cost of installation are considered to be most limiting. Product modification, changes in the distribution and supply system, and a well-rounded marketing and merchandising program by the wood flooring industry are recommended.


## BACKGROUND

### THE URBAN REHABILITATION FLOORING MARKET

In the past, flooring has been marketed for new residential construction more than for the rehabilitation of urban housing.[1] Little attention and few flooring products were directed toward this relatively small segment of the residential construction market.

During the last 10 years, many steps have been taken to improve the quality and quantity of urban housing. Housing rehabilitation has become an integral part of the urban renewal programs of all major cities, and because of this, the rehabilitation flooring market has become larger and more complex.

The largest and most competitive urban rehabilitation market for flooring materials is in housing for low and moderate income families. Based on 1968 estimates of housing construction needs (1), I determined the potential market for flooring in these projects to be as much as 8 billion square feet over the next 8 years. With satisfactory materials available for use, this market will become even larger, more complex, and more competitive as more and larger projects are undertaken.

[1]Urban rehabilitation is the renovation of existing housing units and the demolition of existing units and the construction of new units in their place.

### A PRELIMINARY EVALUATION

To gain a deeper insight into the flooring market in urban rehabilitation and to determine the relative position of hardwood flooring in this market, I conducted a preliminary investigation. Conferences were held with urban rehabilitation personnel and contractors in Boston, New York City, Pittsburgh, Washington, D. C., and New Haven, Connecticut. Various rehabilitation projects were visited and observed; and discussions were held with officials of various Federal and private organizations concerned with building materials and urban rehabilitation.

The investigation showed that floor surfaces in rehabilitated housing have traditionally been wood. In particular, hardwood floors have been considered the most practical and have been used extensively in both new and renovated units throughout the Northeast. In addition, recent studies have shown that wood

flooring is preferred in American housing whenever conditions are suited to its use (*2*, *3*, *4*).

In spite of this preference for wood flooring and its record of residential service. I found the use of hardwood flooring in urban rehabilitation decreasing. This decline is occurring even though the construction of urban housing for low and moderate income families has continued to increase over the last decade. At the same time, the use of nonwood floor coverings in urban rehabilitation has increased.

I concluded (1) that further study was needed on factors that affect the use of hardwood flooring in urban rehabilitation; and (2) that emphasis should be placed on the flooring market in housing for low and moderate income families.

## THE NEW HAVEN CASE STUDY

### SCOPE, OBJECTIVES, AND METHODS

After the preliminary investigation, I conducted a study of flooring use patterns in urban rehabilitation in New Haven, Connecticut. An intensive evaluation of one city was preferred to a more extensive survey of several cities.

It was judged that an in-depth study of a representative city would be more practical; and that such a study would produce useful and reliable findings. My investigations indicated that urban rehabilitation construction methods, regulations, funding, and other requirements are fairly uniform throughout the country from city to city.[2]

New Haven was selected because it was considered to be representative of most cities in the United States that carry out housing rehabilitation in their urban renewal programs. It is a mediun sized city comprised of industrial, government, business, and academic elements and one where considerable experience and expertise in urban rehabilitation can be found.

The objectives of the study were: (1) to determine the factors that influence the use of hardwood flooring in urban rehabilitation; (2) to determine which problem areas were most critical and where improvement would be most likely; and then, on the basis of these findings, (3) to suggest possible solutions.

Data and information were obtained through personal interview, through review of the city's files and publications, and by visits to rehabilitation sites.

### THE INTERVIEWS

Interviews were held with the New Haven Redevelopment Agency, the City Plan Department, two nonprofit housing development corporations, two private housing construction firms, and one private architectural firm. Thirty-five executive personnel, construction supervisors, inspectors, and architects participated in the interviews.

During the interviews the participants were asked to respond to 48 questions contained in a structured, open-ended questionnaire. The questions covered such topics as the agency's function and experience in urban rehabilitation, the construction and renovation of low and moderate income family housing, the use of hardwood flooring and other wood products in the construction and renovation, wood flooring and other wood products trends, desirable attributes of flooring materials, the advantages and disadvantages of various types of surface flooring, and the flooring selection process.

With the exception of the City Plan Department and the private architectural firm, all of the agencies and firms that were interviewed sponsor or construct housing for low and moderate income families. The Redevelopment Agency sponsors most of the city's housing rehabilitation. The agency, through its neighborhood improvement offices and city field offices, is responsible for urban rehabilitation specifications and quality. The City Plan Department examines and approves the plans for all housing constructed in the city.

One of the private construction firms interviewed is the largest building contractor en-

[2]More detailed information pertaining to the preliminary investigation and the case study may be obtained from the author or his USDA Forest Service unpublished manuscript "Urban Rehabilitation, Characteristics, Methods, and Requirements and Their Effect Upon the Use of Hardwood Flooring and Other Building Materials."

gaged in rehabilitation within the city. It performs both turn-key and contract work. The two nonprofit housing development corporations are the city's largest and oldest. The architectural firm has designed all types of housing for both public and private concerns, including much housing for the low and moderate income families.

Most of the people participating in the interviews had from 5 to 10 years of experience in urban rehabilitation and their organizations had been involved in urban redevelopment and rehabilitation for at least 10 years.

## THE RESULTS

### THE FLOORING DECISIONS AND THE DECISION MAKERS

The organizations interviewed were the four groups most closely involved in materials specification and selection. The decisions that these groups make about which flooring materials to use are made when the rehabilitation plans are drafted and when the budget is set. Their decisions are based on: (1) the quality, specifications, and cost of the materials; (2) the types of materials; (3) the brands; and (4) the sources of supply.

The owners and the builders are the most influential in flooring materials selection. They exercise considerable control in most of the decisions (table 1). In addition, they have the greatest influence in the decision areas that are most important in determining which flooring is used—decisions concerning cost, type, and supply source.

The determination of type of material is the most important decision and it is often affected by decisions concerning costs. Decisions regarding type and cost are made jointly by the contractor and the owner early in the materials-selection process. The selection of the supply sources is made primarily by the contractors and often influences type and cost decisions.

The rehabilitation officials and the architects have little influence on the selection of specific flooring materials. Their responsibilities involve primarily materials specifications and quality standards which must be met by all flooring materials. With respect to flooring selection, their functions are mainly advisory.

### FACTORS THAT DETERMINE THE TYPE OF FINISH FLOORING MATERIALS

Many factors, such as product characteristics, act and interact to determine the type of flooring used. The building contractor and the housing owner give prime emphasis to those product characteristics that affect approval, acceptance, and financing of their units. The contractor is likely to choose a product that he can procure and install easily and cheaply and that he can sell.

Overall, the most important influences are: (1) the availability of the product to the contractor; (2) the cost of the product and associated costs to the contractor and the owner; (3) the compatibility of the product with the construction plan and schedules of the builder and owner; and (4) intangible factors, such as

Table 1.—The relative amount of influence that the people responsible for specifying flooring have on various flooring decisions[a]

| Item | Quality | Specifications | Cost | Type | Supply source | Brand | Purchasing |
|---|---|---|---|---|---|---|---|
| Housing owners[b] | + | − | + | + | − | + | 0 |
| Building contractors | 0 | − | + | + | + | + | + |
| Rehabilitation officials | + | + | 0 | 0 | - | 0 | 0 |
| Architects | 0 | 0 | − | 0 | − | 0 | 0 |

[a] + considerable influence
0 influence, usually in an advisory capacity
− little or no influence

[b] In some instances, a group may be multifunctional, assuming the role and responsibilities of two or more decision makers, such as builder and owner. Often the contractor and the owner are the same.

user preference, image, or product information.

## Product Availability

The urban rehabilitation market needs building materials that are consistently and readily obtainable. If a flooring product is not to be had when and where it is needed, then the other factors affecting its use need not be considered.

The interviewees expressed the opinion that the traditional distribution channels of hardwood flooring are not as satisfactory as those of substitute products. Hardwood flooring was considered more difficult for the builders to obtain than competitive products. Those interviewed indicated that hardwood flooring was handled by fewer suppliers; delayed more often in arrival; and more often in short supply or unavailable in the quality, quantity, and variety needed.

Flooring materials should be provided for urban rehabilitation at a constant rate and at relatively predictable and competitive prices. Unlike conventional residential construction, urban rehabilitation has very little seasonal fluctuaton; the planning is completed well ahead of construction and the construction is on a year-round basis.

In addition, job time and costs are designed and contracted for within given price ranges of products. Changes in the supply or price of any component of the complex upset schedules and budgets for the entire project.

The respondents felt that the supply and prices of nonwood products remain relatively more constant than those of hardwood from season to season and with fluctuations in the cost and supply of raw materials. Additionally, the interviewees felt that hardwood prices rise when the market and economy are good or improving; and often when the market is poor, hardwood flooring is not available at prices that would make it competitive.

## Cost Factors

Next to availability, the building contractor and the housing owner are concerned primarily with factors that affect costs. In most cases, they must bear the initial cost of rehabilitation, and the contractor must absorb any loss on the construction phase of the project.

In comparing flooring materials, the builders and owners consider the total cost. The cost of flooring to them is the combined total of all costs, long and short term, connected with it. While total product cost and long-term cost are important; cost factors that require expenditures of money in the short run, such as purchasing and installation, are even more important.

*Installation Factors.*—Installation includes the actual laying of the flooring and cleaning, surfacing, and finishing. Factors that make the cost of installing a product greater than the cost of installing competing materials place that product at a distinct competitive disadvantage in urban rehabilitation.

Installation time and labor cost are very important in the selection of finish flooring. Because the urban rehabilitation market is highly competitive and because the construction is usually contracted for on a fixed cost basis, installation time and labor costs must be controlled as carefully as possible. It is in these areas that the interviewees found the most serious problems for hardwood flooring.

In its present form, hardwood flooring cannot compete in speed of installation. Contractors felt that a maximum of 2 to 2½ days for a two- to three-man crew was sufficient to install or to renovate 1,000 square feet of flooring. Most resilient sheet flooring and carpet is delivered in 12-foot wide rolls and can be laid in the average dwelling unit within 1 day. Vinyl asbestos tile takes a little longer; but very seldom as long as 2 days. Hardwood strip flooring laid directly on joists or over a subfloor usually requires more than 2 days. Then additional time is needed for sanding, cleaning, applying sealer and finish, and for drying.

In addition to the time difference, the interviewees felt that the installation and finishing of hardwood flooring requires highly skilled labor.[3] Such labor was considered expensive

[3] It is doubtful that more skilled labor is required for wood or that the actual laying of hardwood flooring is any more difficult or critical than the laying of carpet or resilient flooring. More likely, installation problems associated with the use of hardwood are due to such things as faulty installation procedures, improper finishing and finishes, unfamiliarity with the product, and failure to allow for dimensional changes in the wood.

and hard to obtain for hardwood, especially strip flooring.

The interviewees felt that thinner and larger hardwood flooring units, panelized and prefinished, were needed to reduce both the time and the labor required to install hardwood floors. The flooring units should be of a size that two men could handle readily. On this basis, they felt that panelized hardwood flooring, both strip and block, could compete with nonwood flooring in installation time[4] and labor costs.

*Installed Cost.*—An installed cost between 30 and 75 cents per square foot is preferred for finish flooring materials. I found that the installed cost—the costs of acquisition and installation—of hardwood was acceptable and that it compared favorably with the installed costs of other flooring materials commonly used in urban rehabilitation (table 2). Installed costs were considered to be lower for resilient products because of lower distribution costs, because of "deal" purchase prices available to the contractors, and because fewer operations are required to install resilient flooring and prepare it for use.

Table 2.—Interviewees' opinions of installed costs for flooring materials commonly used in urban rehabilitation

| Flooring material | Installed cost (per square foot) |
|---|---|
| Asphalt tile | $0.35 - .45 |
| Vinyl asbestos tile | .40 - .50 |
| Composition sheet | .45 - .55 |
| Hardwood | .55 - .65 |
| Wall-to-wall carpet | .65 - .75 |
| Ceramic tile | 1.00 - 1.60 |

In general, hardwood floors fared well in most cost comparisons with substitute products. However, some of the difficulties and inconveniences that the builder and owner encounter impair hardwood's overall comparative position.

Delays in receiving orders were often cited as a cost disadvantage of hardwood flooring; not so much as a direct cost but as a cost in the disruption of timetables and the rescheduling of work. Quite often hardwood flooring must be purchased from two or more suppliers; this results in loss of time and inconvenience for the contractor.

Hardwood flooring was felt to be more difficult and expensive to protect from moisture. Precautions must be taken to keep it dry and dimensionally stable in storage, enroute to the site, and on the job.

The respondents felt that, during and after installation, hardwood floors are more susceptible to damage than competitive materials. If damaged, they are more difficult and expensive to repair or replace.

## Product Compatibility

If a flooring material is available and the price is acceptable, the product must also be compatible with the construction plan and schedules of the builder to maximize efficiency and minimize time and cost.

The floor construction of the typical new or renovated unit differs little from its conventional counterpart. The finish flooring is installed, replaced, or repaired as close to the end of the construction job as possible, but before interior partitions are erected or finish wall materials applied.

For most hardwood flooring products, the workers must return later to complete the finishing. When speed is essential, nonwood flooring materials that lend themselves to faster installation and that do not interrupt the work flow are used. In addition, most substitute flooring materials are considered easier and less expensive to repair or replace in buildings undergoing renovation.

## Intangible Factors

In addition to availability, cost, and compatibility, the decision as to which type of flooring material will be used is affected by the user's image and associations and by product information. However, none of these intangi-

[4]Although rapid installation is characteristic of carpet and resilient floor coverings, the time required to install both the subfloor and the finish floor covering is the correct time to use for comparison with wood flooring.

ble influences is strong enough to dictate the type of flooring chosen.

Associations and image include user preferences, opinions, tradition, prestige value, ability to blend with decor and furnishings, warmth, acoustical properties, and the way the flooring reacts to grease, solvents, stains, and the like.

Wood flooring products are preferred by people living in the Northeast. Hardwood has an image of being traditional, high in quality, durable, practical, and prestigious. Many architects and rehabilitation officials associate it with higher quality construction.

However, carpet and resilient flooring are often preferred as more modern, fashionable, and versatile. Related to this image are aesthetic appeal, ease of maintenance, the feeling of luxury and of having the latest in luxury products, attractiveness of color and design, and underfoot comfort.

Another factor is the ability of the flooring to blend with the decor of the room, apartment, or project. This factor especially affects the choices of architects and building owners. Most of the interviewees felt that wood flooring was limited in designs and patterns at practical prices; that it was not versatile enough to adapt to the decor of living areas designed with more modern materials.

In addition, it was felt that children and hardwood floors are not compatible—the floors mar and scratch too easily, they are slippery, they are not as resilient as other floors, and they do not absorb shock and sound as well.

One intangible factor that also appears to have a strong influence is the amount and quality of information available on finish flooring materials. The interviewees indicated that the contractor and owner prefer a product that is advertised as new, modern, and up to date; that is adequately guaranteed by the manufacturers; and that is backed by technical assistance from the manufacturer. All those interviewed noted the general lack of unbiased technical information about the various flooring materials.

Most of the people interviewed felt that hardwood flooring is not advertised or promoted as heavily as carpet or tile. The interviewees would like to see flooring producers use more appeals to the senses, more glamorous advertising, wider dissemination of all types of information, more sales aids, more point-of-sale promotion, more representation, and installation training programs.

Generally, governmental and labor union rules impose few restrictions on the choice and use of most finish flooring in new or renovated units. Occasionally, local housing standards restrict the use of hardwood flooring in certain areas such as bathrooms and kitchens. Building trade unions may influence flooring selection through practices that affect time and cost of installation.

The Federal Housing Administration and the Department of Housing and Urban Development impose few restrictions that limit the use of hardwood flooring. Federal regulations generally relate to long-term financing, as do the recently established minimum standards for carpeting in homes with Federally-insured mortgages.

Maintenance, wear life, and other factors can play a governing role in the selection of flooring materials in some residential construction. These factors generally caused no problems in the choice and use of finish flooring in the study area, however.

## SUMMARY AND CONCLUSIONS

Compared to carpeting and resilient flooring, hardwood flooring is a traditional building material with natural beauty. It is identified with ideas of quality, durability, and the like. Hardwood flooring has traditionally been used to a greater extent in urban rehabilitation construction than any other type of finish flooring.

Yet, in spite of its current use, tradition, and people's love of wood, the position of hardwood flooring in the rehabilitation of urban housing is being threatened. Hardwood will not continue to be used in urban rehabilitation unless it becomes more competitive with other materials.

Recognition of and response to the factors that affect the choice of flooring for use in urban rehabilitation will serve to strengthen the hardwood flooring industry's position in this market. Vigorous action taken now can

give the industry a good market for years to come.

Results of the study indicate that in the urban rehabilitation market, it is the economic, physical, or technological factors that dominate product selection. Most factors restricting or preventing the use of wood flooring are related to cost, availability, compatibility, and efficiency.

The attitudes of the housing owners and the building contractors—the two groups most responsible for specifying flooring materials—are based primarily on cost. Most of the cost in time and money associated with hardwood flooring is related directly or indirectly to its methods of installation.

The industry should aim at reducing initial cost, reducing installation time, and reducing the amount of labor and skill required in the installation of its products. The production of prefinished, panelized flooring appears to be a desirable and promising solution. Product modification, changes in distribution and supply, and other reductions in cost can be accomplished with present technology.

The hardwood flooring industry should also be attentive to those influences that might be termed home environment factors. In addition, a well-rounded marketing and merchandising program by the wood flooring industry is considered essential. More vigorous, efficient, and appealing promotion, as well as more adequate technical assistance would definitely be helpful.

Beside the direct benefits that members of the industry would receive from continued or increased attention to the urban rehabilitation market, products and techniques developed for this market should be applicable to other residential and nonresidential construction.

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by Peter W. Garrett
Ernst J. Schreiner
Harry Kettlewood

# Geographic Variation of EASTERN WHITE PINE in the Northeast

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NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

PETER W. GARRETT, Research Plant Geneticist, received a bachelor of science degree at Michigan State University in 1957 and master of science and Ph.D. degrees at The University of Michigan. He was employed in industrial research and teaching before joining the Genetics Project of the Northeastern Forest Experiment Station in 1966. He is currently engaged in the white-pine weevil resistance program at the Forest Science Laboratory, Durham, New Hampshire.

ERNST J. SCHREINER, Research Plant Geneticist retired, received his bachelor of science degree at Syracuse in 1926 and a Ph.D. in plant genetics from Columbia University in 1931. He began his tree breeding work in 1924 and joined the Northeastern Forest Experiment Station in 1936. Dr. Schreiner's responsibilities included improvement of many genera and he has gained world-wide recognition for his work with hybrid poplar.

HARRY C. KETTLEWOOD, Research Technician, was employed on the Boise National Forest in Idaho from 1951 to 1956, when he joined the Genetics Project of the Northeastern Forest Experiment Station. His principal assignment has been in the breeding and evaluation of pine and poplar species at the Forest Science Laboratory, Durham, New Hampshire.

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# Geographic Variation of **EASTERN WHITE PINE** in the Northeast


## ABSTRACT

Eastern white pine is the most valuable conifer in the Northeast, and its large botanical range has provided ample opportunity for the development of ecotypes. Provenance plantings in nine states provided information on variability within the species and recommendations for moving seed from one region to another. Good growth was obtained on southern Appalachian sources moved as far north as central Pennsylvania. Needle length, branching habit, cone production, and other characters are discussed.

## INTRODUCTION

THE NORTHEASTERN Forest Experiment Station held a "White Pine Research Program Conference" at New Haven, Connecticut, in February 1955 to set up priorities for the Station's research with this species. The growth potential of eastern white pine (*Pinus strobus L.*) was well known; but in much of the Northeast, timber quality was a major problem. The primary cause of degrade could be attributed to forest pests, particularly to the white pine weevil (*Pissodes strobi* Peck), which had been responsible for annual losses exceeding 7 million dollars in New England forests alone (*Marty and Mott 1964*). But quality is also affected by the growth rate (distance between nodes), stem form, number and diameter of branches, branch angle, and other factors that may be genetically controlled.

For the Genetics Project, it was concluded that information was urgently needed on racial variation. There was evidence for the existence of racial differences in eastern white pine, but no experiments to provide adequate information about the extent or nature of such genetic variation or the best provenances for use in different parts of the region.

As a follow-up to the Connecticut meeting, representatives of the USDA Forest Service's Southeastern, Lake States, Central States, and Northeastern Forest Experiment Stations, and Dr. Heimburger of the Southern Research Station, Maple, Ontario, conferred on white pine racial tests in Washington, D.C., on Au-

Table 1.—Location and design of plantations

| Plantation No. | Location | Field design | Lat. | Long. | Elev. (feet) |
|---|---|---|---|---|---|
| *Established by Northeastern Station:* | | | | | |
| 1 | Orono, Maine | III | 44°53′N | 68°39′W | 100 |
| 2 | Alfred, Maine | I, II, III | 43°32′N | 70°40′W | 300 |
| 3 | Essex Junction, Vermont | III | 44°28′N | 73°09′W | 327 |
| 4 | Paul Smiths, New York | I | 44°26′N | 74°13′W | 1,815 |
| 5 | Williamstown, Massachusetts | I | 42°44′N | 73°14′W | 1,050 |
| 6 | Warren, Pennsylvania | I | 41°50′N | 79°15′W | 1,180 |
| 7 | Standing Stone, Pennsylvania | III | 40°37′N | 78°55′W | 960 |
| 8 | Kennett Square, Pennsylvania | I | 39°52′N | 75°41′W | 400 |
| 9 | Savage River State Forest, Maryland | III | 39 40′N | 79°15′W | 2,740 |
| 10 | Horseshoe Run, West Virginia | I | 39 11′N | 79°35′W | 1,720 |
| 11 | Rison, Maryland | II | 38°30′N | 77°20′W | 100 |
| *Established by Central States Station:* | | | | | |
| 12 | Nelsonville, Ohio | IV | 39°28′N | 82°12′W | 700 |
| 13 | London, Kentucky | III C.S. | 36°59′N | 84°17′W | 1,100 |

gust 4, 1955. This group recommended that the same 14 provenances in a standard field design (with 81-tree plots) would be included in at least one outplanting in each region, and that any number of additional provenances could be included in other field designs.

Eleven of the 13 provenance plantations evaluated in this report were established by the Northeastern Station; 2 plantations were established by the former Central States Forest Experiment Station (table 1).

## MATERIAL AND METHODS

### Seed Collection

Seed for the Northeastern Station's tests was supplied by cooperators from 32 provenances (fig. 1, table 2). Instructions for seed collection were as follows:

> All seed must be from trees in naturally regenerated stands; they may be either pure stands of white pine or white pine in mixture with other species.
>
> Approximately 25 cones should be collected from each of 10 trees chosen at random over an area of 5-10 acres, or approximately ¼ mile of forest road in a good stand. Trees in openings or border trees may be chosen for ease of cone collection *provided they are definitely of natural origin.* Squirrel-cut cones may be collected from the ground if they can be assigned with reasonable certainty to a single tree.
>
> *The cones from each tree should be packed in separate bags* for extraction at the Northeastern Station.

### Nursery Stock

The Northeastern Station's outplantings in 1959 (plantations 7 to 11) were established with 2-0 stock grown in the Maryland State Forest Nursery. The 1960 plantations (1 to 6) were established with 3-0 stock grown in the New Jersey and New York State Forest Nurseries.

Seedlots were kept separate by individual seed trees through the nursery phase of this study for two reasons: (1) to allot (for outplanting) approximately the same number of seedlings from each of the seed trees represented in a provenance; (2) for information on juvenile variation between one-parent progenies from the same provenance (*Santamour 1960*).

The seed for the Central States plantations was extracted, bulked by provenance, and grown at the Ralph Edwards Nursery in North Carolina.

## FIELD TEST LOCALITIES

The Northeastern Station established plantations in 12 localities to sample the environmental conditions under which eastern white pine might be planted in the region: 3 in Pennsylvania; 2 each in New York, Maine, and Maryland; and 1 each in Massachusetts, Vermont, and West Virginia (fig. 2). (One of

Figure 1.—Map of seed sources used in the provenance tests. Shaded areas show the natural range of eastern white pine. Numbers indicate seed-collection points (table 2).

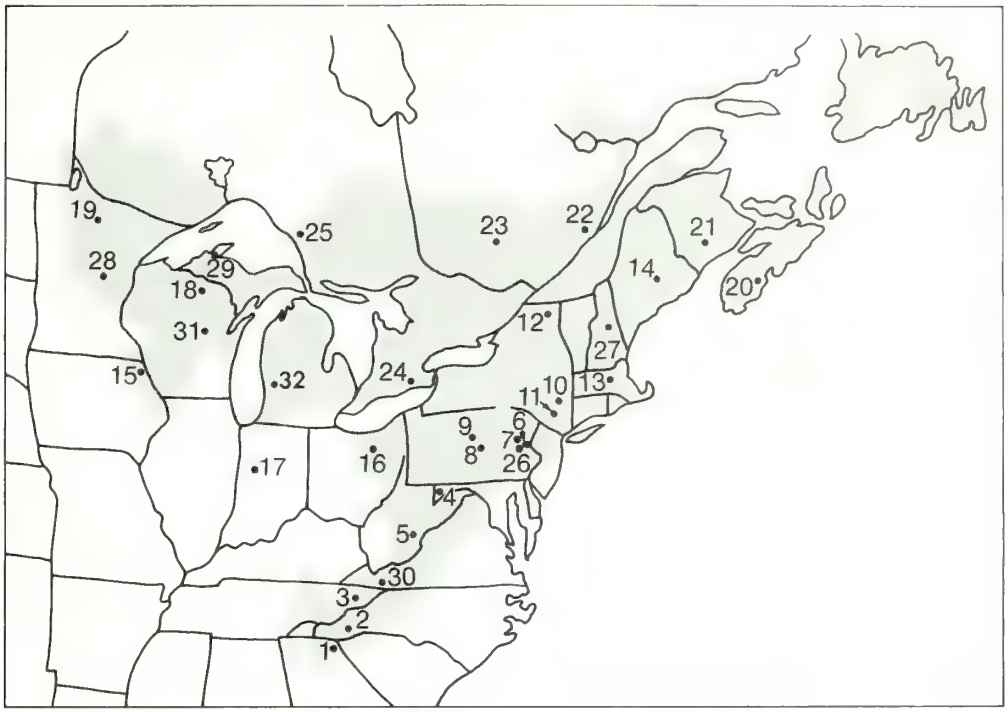
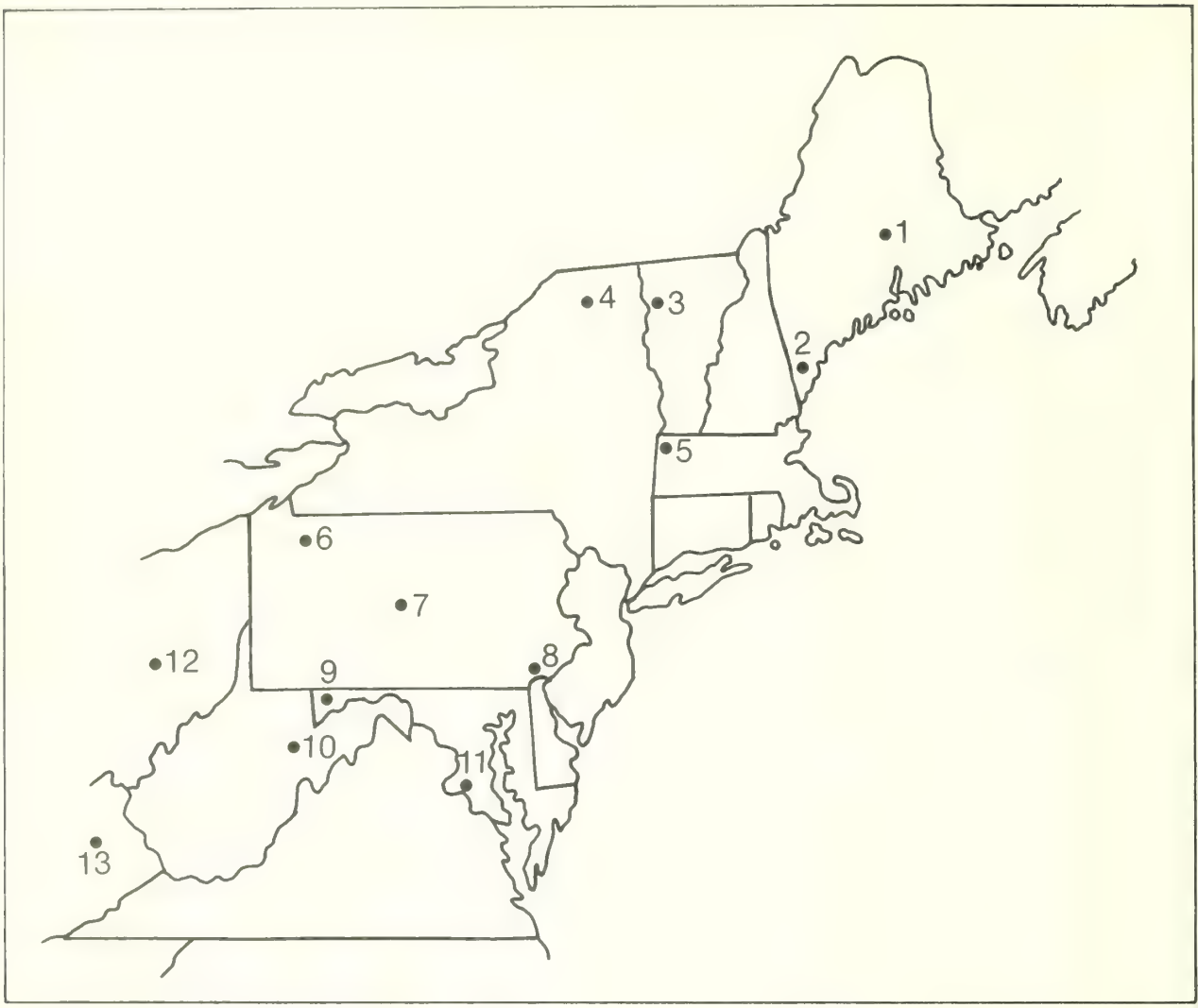



Table 2—Seed source locations for white pine provenance study

| Seedlot No. | Location | Lat. | Long. | Elev. (feet) |
|---|---|---|---|---|
| 1 | Union County, Georgia | 34°46′N | 84°03′W | 2,450 |
| 2 | Transylvania County, North Carolina | 35°14′N | 82°38′W | 2,120 |
| 3 | Greene County, Tennessee | 36°00′N | 82°48′W | 2,250 |
| 4 | Garrett County, Maryland | 39°39′N | 78°45′W | 2,460 |
| 5 | Greenbrier County, West Virginia | 38°00′N | 80°30′W | 2,600 |
| 6 | Monroe County, Pennsylvania | 41°05′N | 75°25′W | 1,800 |
| 7 | Monroe County, Pennsylvania | 41°05′N | 75°25′W | 740 |
| 8 | Clearfield County, Pennsylvania | 41°00′N | 78°30′W | — |
| 9 | Clearfield County, Pennsylvania | 41°00′N | 78°30′W | — |
| 10 | Ulster County, New York | 41°45′N | 74°15′W | — |
| 11 | Ulster County, New York | 41°45′N | 74°15′W | — |
| 12 | Franklin County, New York | 44°25′N | 74°15′W | 1,600 |
| 13 | Worcester County, Massachusetts | 42°30′N | 72°15′W | 1,275 |
| 14 | Penobscot County, Maine | 44°51′N | 68°38′W | 150 |
| 15 | Allamakee County, Iowa | 43°15′N | 91°30′W | 1,000 |
| 16 | Ashland County, Ohio | 40°45′N | 82°15′W | 1,000 |
| 18 | Forest County, Wisconsin | 45°30′N | 88°30′W | 1,500 |
| 19 | Cass County, Minnesota | 47°30′N | 94°30′W | 1,300 |
| 20 | Lunenburg County, Nova Scotia | 44°25′N | 64°35′W | 150 |
| 21 | Sunbury County, New Brunswick | 46°00′N | 66°15′W | 200 |
| 22 | Quebec County, Quebec | 47°30′N | 72°00′W | 550 |
| 23 | Pontiac County, Quebec | 47°30′N | 77°00′W | 1,000 |
| 24 | Norfolk County, Ontario | 42°40′N | 80°27′W | 750 |
| 25 | Algoma District, Ontario | 46°10′N | 82°37′W | 650 |
| 27 | Carroll County, New Hampshire | 43°45′N | 71°25′W | 610 |
| 28 | Lake County, Minnesota | 48°00′N | 91°45′W | 1,300 |
| 29 | Houghton County, Michigan | 47°00′N | 88°30′W | 625 |
| 30 | Pulaski County, Virginia | 37°00′N | 80°50′W | 2,400 |
| 31 | Sauk County, Wisconsin | 43°30′N | 89°30′W | 1,000 |
| 32 | Newaygo County, Michigan | 43°30′N | 85°40′W | 600 |

Figure 2.—Location of white pine provenance planting sites (table 1).




the New York plantings, near Antwerp, was destroyed when the same location was machine-planted by the State and reference stakes were lost.)

Two additional plantings near New Haven, Connecticut, were established by Northeastern Station entomologists for evaluation of weevil damage; the results of their research are not included in this report.

The Central States established the plantations in Nelsonville, Ohio, and London, Kentucky (table 1).

The number of seeds in some collections was not sufficient to permit planting all 32 provenances at each test location, and the actual number of sources varied from 17 to 29.

## FIELD DESIGNS

*Design I.*—Two trees of each provenance were planted 6 to 10 inches apart at a spacing of 10 x 10 feet in 24 randomized blocks (replicates). The purpose in planting two closely spaced trees was to reduce the need for replanting failed one-tree plots. At the end of the second year, when the trees were well established, one tree was removed from each planting spot.

*Design II.*—Two-tree row-plots of each provenance were planted in 24 randomized blocks. Provenance trees were spaced 7 feet in rows 14 feet apart. The intervening (alternate) rows were planted with filler trees to ob-

tain a spacing of 7 x 7 feet. There were two rows of border trees around the plantations.

*Design III.*—Four-tree row-plots of each provenance, spaced 7 feet in rows 14 feet apart, were planted in 12 randomized blocks. As in Design II, filler trees were used to obtain a spacing of 7 x 7 feet, and two rows of border trees were used.

*Design III C.S.*—This Central States design was a complete randomization of twelve 4-tree row-plots in a single block, with spacing, fillers, and border trees as in Design III.

*Design IV.*—The decision of the conferees at the Washington meeting called for a "large-plot" design, with 14 provenances, in each region; 81-tree plots of each provenance, in 4 randomized blocks, planted at 7 x 7 feet spacing with 2 border rows around each block. This design would require 3.64 acres *per block without the border trees.*

The Nelsonville, Ohio, plantation, established by the Central States Station, is the only design IV plantation included in this report.

A design IV was included in the Northeastern Station working plan, but in 1960 there was no suitable area of cleared land available to the Station for such a large design. Four blocks of 81-tree plots with different numbers of provenances were established at Alfred, Maine, on heavily revegetated pasture land. The blocks were extremely irregular, both in topography and natural vegetation (brush and 5- and 6-inch d.b.h. tree growth, mostly aspen). There was no labor available to clear this land either before or after planting; so this plantation has not been included in this report.

## PLANTATION SITES, SITE PREPARATION, AND AFTER-CARE

There has been no systematic or detailed analysis of climates or soils for any of the plantation sites, but there are obvious and contrasting local differences that may affect growth and development. With one exception (Paul Smiths, N. Y.) all plantations were established on old fields. The Northeastern Station plantations were sprayed, where necessary, for control of the white pine weevil; they will be sprayed as necessary until the leaders are beyond reach of the back-pack sprayer.

1. *Orono, Maine:* This planting is on the Penobscot Experimental Forest. The site is flat with a fairly heavy textured soil, permitting only moderate drainage. Spring site preparation (scalped furrows) was planned, but was not possible because the ground was too wet. Severe frost-heaving occurs in the area, but it did not contribute significantly to mortality in this planting. The site is considered a fair to moderate pine site in ths area.

2. *Alfred, Maine:* These plantations are on gently sloping abandoned farmland leased to the Forest Service by P. Chadbourn. They are adjacent to the Massabesic Experimental Forest. Design I (plantation GP-4-60) is located on the upper portion, design II (GP-5-60) is in the midsection of the slope, and design III (GP-6-60) is at the lower end. The soil on the upper portion of the slope appears to be rather shallow, possibly indicating topsoil erosion in the past; but generally the site is good, and growth reflects this condition. The trees were bar-planted in scalped furrows made with a planting machine.

3. *Essex Junction, Vermont:* This is an exposed, gently sloping old pasture site. The soil is heavy, but drainage appears fair to good. Two replicates had to be planted on an area scalped for topsoil; the remaining replicates were planted in sod.

4. *Paul Smiths, New York:* The plantation slopes down into an artificial pocket formed by highway construction. Most of the mortality and climate-induced damage occurred in the lower end of this "cold" pocket. A general improvement in height and vigor was apparent on the higher portions of the slope.

   This was an old clearcut forest site with sparse brush cover. Site preparation consisted of plowed furrows spaced 10 feet apart; the trees were planted in 3-foot circular scalps at 10-foot intervals along the furrows.

5. *Williamstown, Massachusetts:* This was an old hay field with very little woody vegetation. The soil is only moderately fertile and has a tendency to become droughty during most of the growing season. Two-foot-wide strips were mowed at 10-foot intervals to facilitate planting.

6. *Warren, Pennsylvania:* This plantation is on an old-field flood plain ideally suited for growth of this species. There was no site preparation. Approximately one-half of the replicates were lost to new highway construction since the 10th-year remeasurements.

7. *Standing Stone, Pennsylvania:* This is an exposed hilltop in gently rolling terrain. Soil fertility is probably fair to good, but the exposed nature of the site may contribute to less than optimum growth when compared to the general area. Inadequate soil moisture in spots during several very dry summers probably contributed to mortality. The plantation site was plowed and disked before planting.

8. *Kennett Square, Pennsylvania:* This plantation is on fertile, gently sloping farm land on the grounds of Longwood Gardens, maintained by Longwood Foundation, Inc. The plantation included contour strips of sod land, fallow land (corn in 1957), and corn land (corn in 1958). The area is kept mowed and most of the early mortality was due to this practice.

9. *Savage River State Forest, Maryland:* The plantation is on an exposed, somewhat eroded slope facing the prevailing winds. The field was in corn in 1957; it was seeded in 1958 and carried a light sod at the time of planting. There was no site preparation.

10. *Horseshoe Run Recreation Area, West Virginia:* This is an excellent site; bottomland subject to overflow at the base of a steeply wooded slope, with an accumulation of topsoil from the slope and flood deposits from the small stream. The water table is optimum for plant growth, and the narrow valley affords protection from adverse weather conditions. The field was plowed and harrowed before planting.

11. *Rison, Maryland:* This planting, on the General Smallwood State Park grounds, is level and probably has adequate moisture and nutrients for good white pine growth. Weeds and sweetgum, sassafras, and ash reproduction were mowed at the end of the first, second, and third growing seasons. The field was in corn in 1958; there was no site preparation before planting.

12. *Nelsonville, Ohio:* This plantation was established by the Central States Station on the Wayne National Forest. The field had been limed and fertilized for pasture by permittees and therefore was more fertile than typical old pastures. The soil is a silt loam, and the site has a slight west-facing slope. Early maintenance included mowing and chemical weed control.

13. *London, Kentucky:* This plantation was established by the Central States Station on the Baldrock Experimental Forest. The site is level, and the soil is a silt loam. The field was disked before planting, and herbicides were used to eliminate brush competition the first season.

## MEASUREMENTS AND OBSERVATIONS

At the end of 10 growing seasons from seed (nursery-planted in 1957), the following measurements and observations were recorded for all trees in the Northeastern Station plantations: (1) survival; (2) 10-year height; (3) the following measurements from the third whorl from the top—number of branches, branch angle, and needle length (average of 5 fascicles taken from center of current season's growth); (4) frost and snow damage; (5) disease, weevil damage, and injury due to insects other than weevils; (6) secondary flushing; (7) presence of cones; and (8) forks and offsets.

Data supplied by cooperators on the Central States Station's Ohio and Kentucky

plantings included: survival, heights at several ages, branch measurements, and occurrence of proleptic growth.

## RESULTS AND DISCUSSION

### Survival

Wright, *et al.* (*1963*) reported significant differences in survival in two lower Michigan plantings, but most of the mortality occurred in the first year following planting and was probably due to seedling handling at the time of planting and not differences in site adaptability.

Sluder (*1963*) found significant differences in provenance survival in Georgia, North Carolina, and Virginia plantings; but the differences were not correlated with latitude of seed sources. Fowler and Heimburger (*1969*) reported over 95 percent survival for all sources in two plantings in southern Ontario (lat. 42°30′N and 44°05′N), and survival of seed source was not correlated with seed source latitude.

Survival (10th year) was generally good (84 to 99 percent) in our 15 plantings located in a number of climatic zones—from Rison, Maryland, (lat. 38°30′N) to Orono, Maine (lat. 44°50′N). Provenance survival was significantly correlated with provenance latitude only in Massachusetts (5) and New York (4). Both were positively correlated at the 0.01 level.

There were slight non-significant trends in our data to suggest that local sources may survive better in the North and South, but source becomes less important in mid-range latitudes. However, these slight differences in survival are probably far less important than either growth rate or pest resistance within the geographic range of our outplantings.

### Height at Age 10

Results from white pine provenance plantings in the Central States Region indicate that southern sources, with the possible exception of Virginia (30) outperform northern source trees (*Wright 1970*). Funk (*1970*) reported similar results in Indiana and Illinois, but not in Iowa, suggesting that Iowa may be near the northern or western limit for superiority of southern Appalachian provenances.

Based on growth data collected in the Lake States, King and Nienstaedt (*1968*) reported that northern Michigan, Minnesota, and Wisconsin all appear to be north of the line where southern sources outperform local sources (the southern Ontario source—24—does well in these areas). The southern portion of Michigan's lower peninsular is probably below the line, because southern Appalachian sources do well in that area.

Sluder (*1963*) established plantings of southern Appalachian provenances in three southeastern states and found that height growth was correlated with latitude of seed source. Faster growth occurred on southern source trees and slower growth on northern source trees. Genys (*1968*) reported similar results in Maryland.

Several plot sizes (1-, 2-, 4-, and 81-tree plots) were included in our study. The mean and variance were calculated for each plot containing two or more living trees. No relationship was found between mean and variance, and no difference in variance due to plot size was found. Variances were subsequently pooled over all plots, blocks, and locations, except for location 2-59 (central Pennsylvania) where the variances were too high.

Because all provenances were not represented at all locations, Scheffe's S-method was used to test hypotheses of interest (table 3). The results indicated significant differences

Table 3.—Selected comparisons, using Scheffe's S-method

[Location vs. all provenances]

| Plantation No. | Location | Significance |
|---|---|---|
| 1-59 | Southeastern Pennsylvania | n.s. |
| 2-59 | Central Pennsylvania | * |
| 3-59 | Southern Maryland | * |
| 4-59 | Western Maryland | n.s. |
| 5-59 | West Virginia | * |
| 1-60 | Massachusetts | n.s. |
| 2-60 | New York | n.s. |
| 3-60 | Northwestern Pennsylvania | * |
| 4-60 | Southern Maine (I) | * |
| 5-60 | Southern Maine (II) | n.s. |
| 6-60 | Southern Maine (III) | * |
| 7-60 | Central Maine | n.s. |
| 12-60 | Vermont | n.s. |

Figure 3.—Correlation of provenance height with provenance latitude at all planting sites.

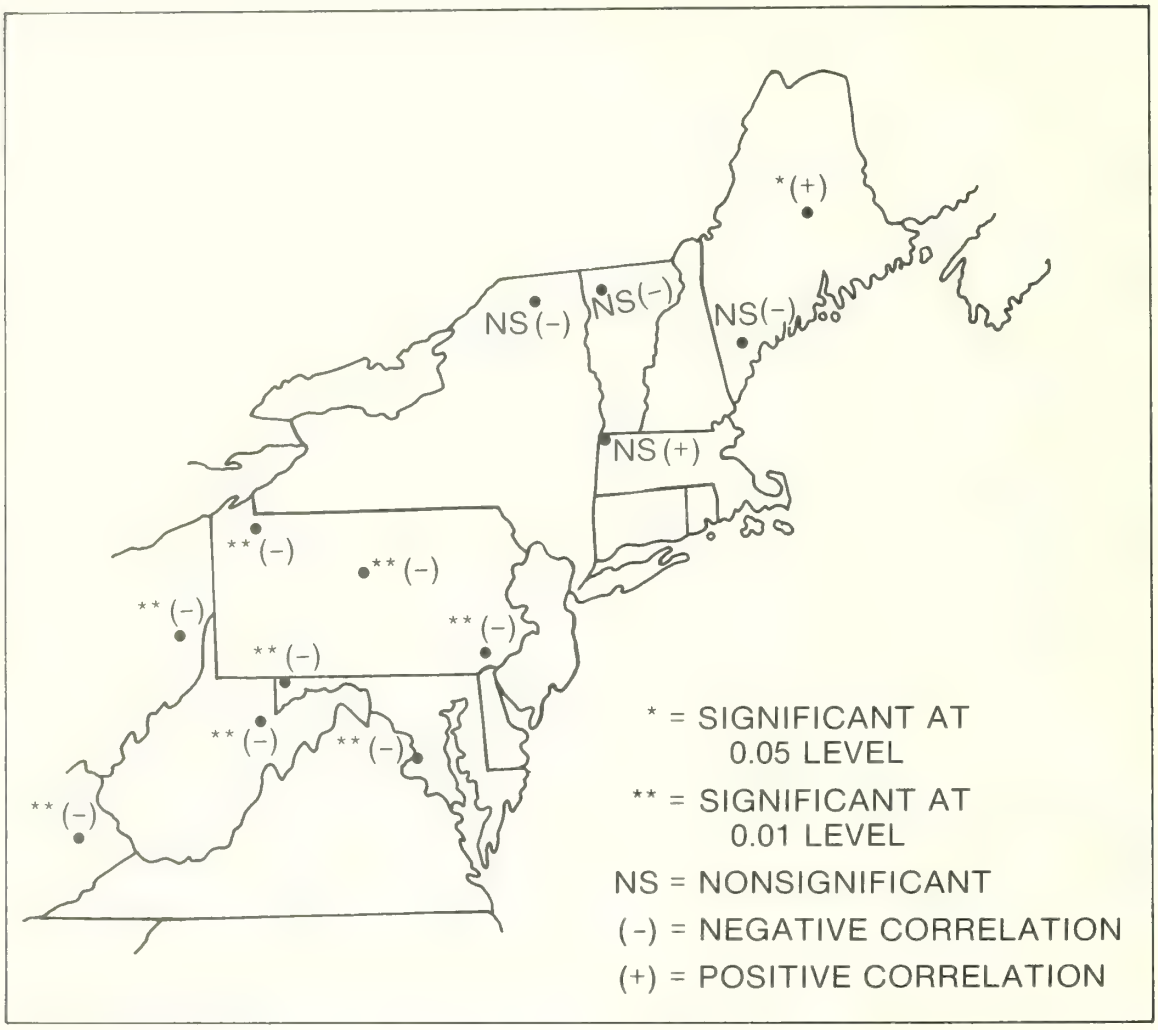



Table 4.—Correlations between several parameters at age 10: White pine provenance study

| Plantation | No. | Source latitude/Tree height | Number branches/Source latitude | Tree height/Needle length | Source latitude/Needle length |
|---|---|---|---|---|---|
| Kentucky | 6-59 | −.8670** | — | — | — |
| Southern Maryland | 3-59 | −.8145** | +.2882ns | +.8931** | −.4806* |
| Central Pennsylvania | 2-59 | −.7292** | −.4622* | +.8269** | — |
| Ohio | 7-59 | −.6890** | — | — | −.6429* |
| West Virginia | 5-59 | −.6788** | +.4745* | +.8597** | −.7917** |
| Western Maryland | 4-59 | −.6659** | +.4882* | +.7720** | −.8533** |
| Northwestern Pennsylvania | 3-60 | −.6307** | +.1594ns | +.6315** | −.7095** |
| Southeastern Pennsylvania | 1-59 | −.5230** | −.0156ns | +.8100** | −.3118ns |
| Vermont | 12-60 | −.3161ns | +.5426** | +.6240** | −.6320** |
| Southern Maine | 6-60 | −.1787ns | +.4477* | +.6799** | −.7214** |
| Southern Maine | 4-60 | −.1379ns | +.4905** | +.0565ns | −.5798** |
| Southern Maine | 5-60 | −.0652ns | +.7598** | +.3210ns | −.7656** |
| New York | 2-60 | −.0253ns | +.4530* | +.7973** | −.3439ns |
| Massachusetts | 1-60 | +.0789ns | +.6112** | +.1560ns | −.3493ns |
| Central Maine | 7-60 | +.3964* | +.6822** | +.8519** | +.3452ns |

between provenances in 6 of 13 locations. Four of these were among the five fastest growing plantations based on average height of all sources. Plantation height generally reflected the existing site conditions, and a strict geographic pattern did not occur.

Height was correlated with provenance latitude in both the upper and lower latitude plantations but not in the mid-range plantations (fig. 3, table 4). In the West Virginia, Maryland, Pennsylvania, Ohio, and Kentucky plantings, trees from southern sources (other than Virginia) were tallest, while northern source trees were tallest when planted in central Maine. Seed-source latitude was not a factor in height growth in New York, Vermont, or southern Maine.

Results from our 15 plantations (13 locations) in the Northeast indicate that southern sources should do very well in all but the northernmost locations (table 5). On the basis of 10-year growth, we would recommend that southern Appalachian (Georgia, Tennessee, North Carolina), southeastern New York, eastern Pennsylvania, and Ontario sources be planted as far north as central Pennsylvania; that southern provenances and provenances from Pennsylvania and southeastern New York be considered in the zone between latitudes 40° and 45°N; and that only provenances from above latitude 40°N be used in central and northern Maine. The poor growth of the Quebec provenances in all the plantings, and the relatively poor performance of the Virginia source, suggest that seedlings from those sources should not be included in future planting programs.

Santamour (*1960*) and Sluder (*1968*) have suggested that seedlings of southern sources, when moved north, either grow at a faster rate or utilize a greater portion of the growing season than northern sources. If this movement does not exceed certain limits (approximately latitude 43°N) the trees are able to harden off in time to escape damage by early fall frost. If moved too far north, however, spring frost damage keeps net growth below that of northern sources. This may be a factor in some areas, but we did not observe frost damage in our northern most plantation, where latitudes and heights or provenances were positively correlated.

### Number of Branches

We were interested in the possible relationship between seed source and number of branches. Number of branches on the third whorl from the top was chosen as an indicator of branchiness. The correlation of latitude of planting and number of branches (all sources combined) was not significant ($r = .4617$). The correlation between average height and number of branches in a plantation, however, indicates that plantations with the tallest trees also have the most branches ($r = +.914$).

The correlation of number of branches with provenance latitude, computed separately for each plantation, was positive in all cases except the plantations in central and southeastern Pennsylvania (table 4).

The southern seed sources definitely had fewer branches in our northern plantations, but differences between sources tend to diminish and finally disappear entirely in the southern plantations. Funk *(1970)* also reported greater growth and fewer branches on southernsource trees grown in Indiana and Illinois.

### Needle Length

Needle lengths were not measured in the Ohio and Kentucky plantations.

Average height of trees in the other plantations was correlated with average needle length of all provenance trees in the plantation ($r = +.644$). When individual provenances within plantations were analyzed, the correlations were always positive indicating that the tallest sources have the longest needles. In 10 of 13 plantations it was significant at the .01 level of probability, and in the other 3 it was positive but nonsignificant (table 4) (Massachusetts, two at Alfred, Maine).

As we speculated with number of branches, this may be a function of tree size at this young age and could very well disappear as the trees grow.

There was also a strong correlation with length of needles and latitude of planting (table 4). With the exception of the northern most plantations, the southern sources produced the tallest trees and had the longest needles. Genys *(1968)* reported similar results for 2-year-old white pine in Maryland.

Table 5.—Relative height of white pine seed source plantations

[Seed-source mean as percentage of plantation mean]

| Seed source No. | Location | SE. Pa 8 | Cent Pa 7 | S. Md. 11 | W Md. 9 | W Va 10 | Ky 13 | Ohio 12 | NE Pa 6 | Mass 5 | N Y 4 | 2 | S Maine 2 | 2 | Cent Maine 1 | Vt 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Georgia | 132 | 130 | 128 | 112 | 119 | 126 | 150 | 129 | 87 | 91 | 98 | 94 | 97 | 80 | 111 |
| 2 | North Carolina | 102 | 120 | 119 | 100 | 110 | 138 | 120 | 98 | 99 | 78 | 93 | 97 | 102 | 79 | 103 |
| 3 | Tennessee | 134 | 124 | 131 | 117 | 115 | 126 | 136 | 120 | 91 | 100 | 102 | 97 | 109 | 82 | 100 |
| 4 | Maryland | 102 | 106 | 101 | 112 | 101 | — | | 119 | 97 | 99 | 103 | 96 | 90 | 82 | 92 |
| 5 | West Virginia | 100 | 89 | 103 | 98 | 106 | 114 | 97 | 98 | 89 | 96 | 86 | 95 | 96 | 91 | 94 |
| 6 | Pennsylvania | 106 | 108 | 103 | 108 | 112 | 117 | 119 | 118 | 103 | 105 | 102 | 109 | 115 | 119 | 112 |
| 7 | Pennsylvania | - | — | — | — | | — | — | | 115 | 102 | 108 | 102 | 105 | 114 | |
| 8 | Pennsylvania | 86 | 103 | 102 | 94 | 105 | | — | | 104 | 114 | 97 | 99 | 97 | 91 | 106 |
| 9 | Pennsylvania | 116 | 113 | 113 | 113 | 122 | — | | 119 | 116 | 113 | 105 | 109 | 118 | 114 | 108 |
| 10 | New York | 110 | 112 | 103 | 101 | 105 | 82 | 78 | 110 | 117 | 118 | 109 | 112 | 114 | 109 | 103 |
| 11 | New York | 133 | 114 | 109 | 111 | 113 | | | 106 | 103 | 126 | 109 | 113 | 109 | 109 | 110 |
| 12 | New York | 108 | 103 | 108 | 108 | 99 | - | | 114 | 93 | 107 | 107 | 102 | 109 | 107 | 105 |
| 13 | Massachusetts | 116 | 103 | 97 | 106 | 116 | — | - | 111 | 101 | 97 | 107 | 110 | 113 | 116 | 106 |
| 14 | Maine | 90 | 94 | 86 | 93 | 93 | 73 | 70 | 94 | 90 | 112 | 106 | 96 | 103 | 111 | 109 |
| 15 | Iowa | 91 | 97 | 95 | — | 95 | 74 | 68 | 98 | 95 | 107 | 94 | 97 | 89 | 102 | 98 |
| 16 | Ohio | 92 | 98 | 101 | 102 | 99 | 113 | 117 | 108 | 105 | 102 | 107 | 106 | 117 | 99 | 110 |
| 18 | Wisconsin | 87 | 76 | 85 | — | — | 108 | 116 | 99 | 102 | 114 | 94 | 98 | 96 | 102 | 94 |
| 19 | Minnesota | 99 | 84 | 89 | 92 | 91 | 72 | 82 | 98 | 97 | 100 | 102 | 101 | 110 | 98 | 93 |
| 20 | Nova Scotia | 87 | 86 | 94 | 91 | 89 | 89 | 95 | 92 | 109 | 84 | 109 | 103 | 98 | 102 | 106 |
| 21 | New Brunswick | 79 | 95 | 94 | 89 | 81 | — | - | 94 | 99 | 80 | 97 | 93 | 88 | 102 | 93 |
| 22 | Quebec | 80 | 82 | 86 | 73 | 71 | 74 | 66 | 69 | 92 | 83 | 96 | 81 | 73 | 84 | 83 |
| 23 | Quebec | 78 | 72 | 76 | 91 | 78 | — | | 31 | | - | 72 | - | 86 | 89 | 86 |
| 24 | Ontario | 105 | 123 | 113 | 111 | 120 | 88 | 99 | 94 | 95 | 86 | 105 | 108 | 109 | 101 | 110 |
| 25 | Ontario | 93 | 97 | 90 | 92 | 95 | — | | 90 | - | | 94 | — | 101 | 106 | 88 |
| 27 | New Hampshire | 112 | 110 | — | — | — | — | | | - | — | 96 | 94 | 109 | 100 | 101 |
| 28 | Minnesota | 92 | 94 | 90 | 94 | 89 | | — | — | | — | — | — | 101 | 112 | 94 |
| 29 | Michigan | 94 | 81 | 85 | 91 | 88 | - | — | — | — | 87 | 99 | 93 | 85 | — | — |
| 30 | Virginia | 81 | 92 | 93 | — | 90 | 103 | 88 | — | | | 103 | — | 71 | - | 86 |
| 31 | Wisconsin | 98 | 94 | 107 | 102 | 100 | — | — | | - | - | - | - | - | - | - |
| 32 | Michigan | — | — | — | — | — | 105 | 107 | - | — | - | - | | - | — | — |
| Plantation mean (ft.) | | 7.1 | 5.8 | 9.0 | 4.8 | 13.1 | 10.1 | 6.0 | 8.4 | 6.1 | 5.3 | 6.8 | 6.8 | 7.4 | 4.1 | 6.5 |

[1]Design I [2]Design II [3]Design III

### Branch Angle

The angle of branch growth from the main stem was measured at the third whorl from the top, and our data indicated that most eastern white pine, regardless of seed source, are similar in this particular characteristic. No significant differences were found between latitude of provenance and branch angle in any of our plantings. Branches tended to be fairly flat (60 to 70 degrees from the main stem) in this study.

A few individual trees had a very pronounced fastigiate branching habit, but this was not related to provenance. Because half-sibs were not identified in the final outplantings, it is not known if the fastigiate types within a provenance came from the same parent trees.

### Frost Damage

The only planting with a measurable amount of external frost damage was at Paul Smiths, New York, and the difference among seed sources were not significant. On the basis of our observations, we would agree with Wright *(1963)* that winter injury is unimportant, at least as far north as latitude 45°N.

No attempt was made to record internal frost injury, and perhaps this should be considered in future measurements. Fowler and Heimburger *(1969)* found that late spring frosts cause some injury to the cambial initials of eastern white pine branches, but no provenance differences were noted in their southern Ontario plantings.

### Snow Damage

Snow damage was observed only in areas where heavy showfalls occur and in slower growing plantations within these areas. The principal damage was separation of lateral branches from the main stem. As the snow encasing the foliage of lower branches settles in the spring, it pulls the branches downward. Damage is usually limited to lower whorls of branches, and permanent external damage rarely occurs on the main stem.

Only in one of the Alfred, Maine, plantings (2-I) were more than a few trees damaged by snow, and provenance was not a contributing factor. Trees from below latitude 40°N had about 12 percent damage, trees from above latitude 45°N had about 10 percent, and provenances between 40° and 45°N sustained about 7.5 percent.

### Insects and Diseases

The major disease of eastern white pine is blister rust (*Cronartium ribicola* Fischer), and programs to eradicate the alternate host in the Northeast have been successful in controlling the disease up to the present time. No rust was observed in any of our plantings at the time of remeasurements, but several infected trees were found at Alfred, Maine, in 1970.

No recognized symptoms of other diseases occurred on any of the trees. There were occasional trees with noticeable yellowing or stunted foliage that we attributed to site conditions, air pollutants, and causes other than diseases.

The only serious insect pest on white pine is the white pine weevil (*Pissodes strobi* Peck). Annual spraying of terminal shoots with Lindane in those plantations growing within the natural range of the weevil (Maine, Vermont, New York, north and central Pennsylvania) was highly successful in controlling weevil damage. Only a few trees that did not receive the complete leader drench necessary for weevil control were damaged.

Populations of this insect have been so high in recent years in the Northeast that most of the trees would have sustained major leader damage, and height comparisons would have been virtually impossible without chemical controls. Plantation 2-I at Alfred, Maine, was not sprayed after the tenth year, and all 27 sources had more than 70 percent leader kill within 2 years. No significant correlations were found between provenance and weeviling under these high weevil population pressures (*Garrett 1972*).

A stem borer, *Eucosma gloriola* Henrich, attacked lateral branches on a number of trees, but caused no damage to main stems. There were a very few light attacks by aphids and what appeared to be damage by other unknown insects.

A few leaders were broken off by snow or

perching birds, and a few buds were removed by birds or squirrels.

### Secondary Flushing

Lammas growth has been defined by Rudolph *(1964)* as: ". . . terminal shoot elongation characterized by one or more periods of growth following the first elongation of the terminal shoot earlier in the season." The condition in which one or more lateral buds at the base of the terminal bud break dormancy and add another flush of growth at the end of the normal seasonal growth is referred to as prolepsis.

Secondary flushing in many species has been observed on trees of southern origin grown in northern latitudes. Genys *(1963)* reported a negative correlation of lammas growth for both latitude and height for 2-year-old white pine in Maryland. In southern Michigan *(Wright et al. 1963)* and in southern Ontario (*Fowler and Heimburger 1969*), the southern provenances produced the fewest lammas shoots. Significant differences were also found between their two plantings in Ontario (28 and 11 percent), suggesting that environmental changes over a short distance can also be important.

We had expected to find considerable late-season flushing in our New York, Vermont, and Maine plantings; but only the southern Maine location has more than a few trees with this type of growth. Lammas growth occurred more frequently than did prolepsis, but there were many trees with both types of secondary flushing.The number of trees in a provenance with late-season growth varied from fewer than 4 to more than 30, but no correlation was found between provenance latitude and lammas growth. The Lake County, Minnesota, source (lat. 48°00′N) had about 9 percent of trees with secondary flushes; the Cass County source (lat. 47°30′N) had almost 31 percent; and Pontiac County, Quebec (lat. 47°30′N), was lowest with slightly more than 3 percent. Tennessee (lat. 36°00′N) ranked second with over 23 percent, while Virginia (lat. 37°00′N) was ranked near the bottom with 5 percent.

Secondary flushing was not recorded for the Kentucky plantation; it was recorded at age 7, but not for age 10 for the Ohio test. In the Ohio plantation, secondary flushing was positively correlated with height ($r = +.662^*$) and negatively correlated with provenance latitude ($r = -.602^*$).

### Cone Production

Very few cones were found in any plantation at the end of the tenth growing season, although some female, flowers were reported at Standing Stone, Pennsylvania, by age 7. In 1966 cones were present on more than 30 percent of four northern sources, and two southern sources had no cones. Male strobili did not occur until 5 years after the first female flowers (*Gerhold, H. D., personal communication*).

Results similar to those in Pennsylvania were found in our plantations as far south as West Virginia, where not a single tree in the six sources from below latitude 40°N had produced a mature cone at age 10.

While we have not had a lot of flowering in our plantations yet, there is good evidence of a positive correlation between latitude of provenance and cone production. The number of cones was definitely higher on northern seed sources than on southern sources.

### Forks and Offsets

Among the suspected causes of stem deformities recorded under this heading were snow damage, terminal-bud feeding by squirrels and birds, shoot damage by weevils, and possibly frost damage. We found it extremely difficult to assign a cause to stem deformity that occurred in past seasons.

Forks and offsets on main stems occurred on a few trees in all plantations, but such deformities were not related to provenance.

## SUMMARY

The results obtained from these plantings and the conclusions reached from them may be summarized as follows:

1. Trees from southern Appalachian sources (Georgia, Tennessee, North Carolina), southeastern New York, eastern Pennsylvania, and southern Ontario should be favored in planting programs at least as far

north as central Pennsylvania (lat. 41°00′N). From central Pennsylvania to southern Maine (lat. 44°00′N), growth of local and southern sources is about equal. Above latitude 45°00′N, the southern Appalachian sources are no longer superior, and Pennsylvania, New York, and local sources should be selected.

2. Needle length is greatest in the southern sources. Because these trees have fewer branches, it may be that total photosynthetic surface does not vary greatly by provenance; however, if photosynthetic surface is greater in southern sources, it could partially explain the superior growth of these sources.
3. Most individual trees have the typical flat branching habit, but fastigiate types not related to provenance do occur.
4. Frost and snow damage is unimportant as far north as latitude 45°00′N. More work needs to be done on the effects of internal frost damage, but it does not appear that this will be correlated with provenance.
5. Diseases were not an important factor in these northeastern tests, and there does not appear to be any relationship between weevil damage and provenance.
6. The relationship of secondary flushing to provenance is not clear; it was more frequent on southern sources in Maryland, but less in Michigan and Ontario. Our results are inconclusive.
7. Cone production was correlated with provenance. Central and northern provenances produced more cones at an earlier age than southern provenances, even in southern plantings.

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# Economic Analysis of the Gypsy Moth Problem in the Northeast

## I. Applied to Commercial Forest Stands

by Roger E. McCay
and William B. White

USDA FOREST SERVICE RESEARCH PAPER NE-275
1973

FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

ROGER E. McCAY received his bachelor of science degree in forest management from Iowa State University in 1966 and his master's degree in agricultural economics from the Ohio State University in 1970. He joined the USDA Forest Service's Northeastern Forest Experiment Station survey project for Ohio in 1966. In 1967 he transferred to the forest economics research project located in Columbus, Ohio.

WILLIAM B. WHITE received a bachelor of arts degree in zoology and botany from Wabash College in 1964 and a master's degree in forest entomology from Purdue University in 1967. He joined the USDA Forest Service's Northeastern Area, State and Private Forestry, at Delaware, Ohio after graduation. He is presently on the Area's Forest Pest Management Staff in Upper Darby, Pa.

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This is the first in a series of publications on the economic impact of the gypsy moth. The next two reports are:

APPLIED TO RESIDENTIAL PROPERTY

APPLIED TO RECREATION

Future publications in the series are in preparation.

# Economic Analysis of the Gypsy Moth Problem in the Northeast

## I. Applied to Commercial Forest Stands


## ABSTRACT

A method of calculating immediate and future losses caused by the gypsy moth is presented, using examples of pulpwood and sawtimber stands. Discounting of future losses to evaluate their cost in terms of current expenditure is explained. The effect of infestation on forest management is discussed and a format is given for considering control decisions.

# INTRODUCTION

ECONOMIC EVALUATIONS are prerequisite to sound forest insect management decisions. In the past, many insect control decisions have been made without sufficient economic analysis. The value of insect suppression may be reflected in the form of dollars, job opportunities, aesthetics, or other benefits. This paper presents an approach that the authors employed in evaluating timber product loss from gypsy moth defoliation.

The model provides a vehicle for evaluating local opportunities for gypsy moth control using appropriate economic inputs e.g., treatment costs, return values and discount rates. Case studies showing the application of the method in pulpwood and sawtimber stands are presented. We also explain how uncontrolled gypsy moth infestation can limit timber management decisions.

# METHODOLOGY

Estimation of stand value loss requires the following basic data: time dimension, extent of damage, and stand value. The time dimension establishes whether the losses we are dealing with are immediate or in the future. Immediate losses are evaluated by direct calculations using today's costs and values on existing merchantable timber. To calculate future losses we require information or assumptions about future growth rates, timber products, timber values, interest rates, and recurring defoliation.

Many times the most difficult part of an economic analysis is obtaining estimates of the extent of the damage. In many instances these estimates are divided into general categories. For example, a certain insect may kill a specified percentage of white oak trees, but only the low vigor white oak trees may be killed. The best estimates of value are obtained when the damage estimates are as specific as possible about the nature of the damage and the kinds of trees involved.

Forest stands are valued for many reasons. Some areas are important for timber production, other areas are valued for wildlife or scenic beauty, while still other areas have recreation values. Any of these values could be used in an economic analysis if the value is quantifiable. To estimate stand value loss we must be able to define and quantify the value that may be lost and determine how the lost value affects the residual value both now and prospectively.

The possibility exists that part of the value of trees lost will be compensated for by increased growth of the remaining trees. This factor has been ignored in the following examples. We also ignore retardation of growth in trees not killed by defoliation.

Immediate stand value loss for timber products is calculated as follows: Value loss for each class of trees (the same species, diameter, merchantable height, and quality) equals the mortality rate for that class times its total value. Total stand value loss is the sum of the losses in each class.

Some of the value loss may be recovered if the trees lost are merchantable and may be marketed immediately. The merchantability and market conditions for dead trees vary by locality, therefore for simplicity we have not included this value in our examples.

For the future loss calculations, the number of years until harvest must be estimated. The harvest age may be derived from tree growth rates and merchantability standards. Estimates for the value of the harvest and the per-

centage loss are required. The basic formula for the future stand value loss is as follows:

**Formula 1.** Future stand value loss in terms of current dollar values.

Expected value loss = harvest value X mortality rate.

Discount expected value loss to obtain a measure of the amount of money which, if invested now at the specified rate of compound interest, would equal the expected loss when the stand reaches harvest age.

$$\text{Value loss in current dollars} = \frac{\text{expected loss}}{(1+i)^n}$$

where: i = interest rate
n = number of years until harvest

Most stands are too large for us to have information on every tree, therefore sample information that is representative of the whole stand must be taken. The sample information should be averaged and then multiplied by the proper sample-to-stand ratio to arrive at total stand value loss.

## Case Study I – Calculating Immediate Loss in a Pulpwood Stand

Our first case study examines a pulpwood-size stand to determine the loss that would be caused by one year of heavy gypsy moth defoliation. Campbell and Valentine (*1*) have developed estimates of tree mortality based on defoliation histories and tree characteristics. We used the percentage tree mortality expected over a three year period (N+3) after one year of heavy defoliation (H). This percentage is most likely to include all the tree mortality that will result from one heavy defoliation.

Individual tree data were taken from 26 1/10-acre fixed plots. The tree data were summarized and averaged by plot (table 1). Data required to use the mortality tables included tree species, dominance class (dominant, intermediate, or suppressed), diameter class, and crown condition (good, fair, or poor).

The immediate loss is calculated by multiplying the total pulpwood volume, as determined from volume estimates, times $2.50 per cord,[1] times mortality rate, as determined from Campbell and Valentine. The average of the immediate loss values (table 1)—$4.65—is the loss per acre that may be expected by the third year after one year of heavy gypsy moth defoliation.

## Case Study II – Calculating Future Loss in a Pulpwood Stand

For the future pulpwood loss we must estimate the harvest tree size and the number of years needed to reach that tree size in addition to the data collected for the immediate loss. We used 12 inches d.b.h. as harvest size for the pulpwood trees. Increment cores for establishing the average growth rate were obtained from sample trees. The number of years needed to reach harvest size is determined by multiplying the expected harvest tree size (in inches d.b.h.) times the number of years needed to grow one inch in diameter. For our case the calculations were completed as follows:

Average number of annual rings in 1 in. radial growth: 18.3
Average number of years to grow 1 in. in diameter: 9.15
Assume the average tree size at maturity to be 12.0 inches $\therefore$ 12.0 x 9.15 $\approx$ 110 years for harvest
Present age of stand: 60 years
Years remaining to maturity: 50

The value at maturity requires an estimate of the average merchantable volume at maturity. For simplicity, we will assume the pulpwood values to be constant over time. The maturity value is then multiplied by the percentage of volume lost to obtain the value of the loss. This loss value should be discounted to arrive at a figure in terms of today's dollars, as shown below.

Average merchantable volume at maturity:
Average d.b.h. = 12.0 inches
Average merchantable height at maturity = 32 feet

[1]Pulpwood values based on $2.50 per cord and 90 cubic feet per cord were used for value estimates.

Table 1.—Pulpwood value loss

| Plot | Number of trees per plot (1/10 acre) | Average tree d.b.h. | Pulpwood[a] value per acre | Mortality[b] loss | Immediate value loss per acre |
|---|---|---|---|---|---|
| | *Number* | *Inches* | *Dollars* | *Percent* | *Dollars* |
| 1 | 48 | 5.7 | 36.80 | 7.6 | 2.80 |
| 2 | 33 | 6.7 | 43.26 | 9.0 | 3.89 |
| 3 | 19 | 6.9 | 23.50 | 9.0 | 2.12 |
| 4 | 40 | 5.9 | 32.86 | 12.0 | 3.94 |
| 5 | 38 | 6.3 | 44.96 | 13.0 | 5.84 |
| 6 | 31 | 6.7 | 40.40 | 9.0 | 3.64 |
| 7 | 24 | 7.4 | 43.76 | 10.0 | 4.38 |
| 8 | 22 | 7.5 | 44.46 | 7.0 | 3.11 |
| 9 | 23 | 6.7 | 32.36 | 13.0 | 4.21 |
| 10 | 20 | 6.6 | 28.80 | 10.0 | 2.88 |
| 11 | 20 | 7.5 | 40.70 | 8.0 | 3.26 |
| 12 | 26 | 7.6 | 59.36 | 8.0 | 4.75 |
| 13 | 22 | 7.2 | 54.10 | 4.0 | 2.16 |
| 14 | 32 | 5.9 | 30.80 | 8.0 | 2.46 |
| 15 | 48 | 6.0 | 44.80 | 18.0 | 8.06 |
| 16 | 59 | 5.4 | 36.60 | 16.0 | 5.86 |
| 17 | 47 | 5.7 | 35.80 | 18.0 | 6.44 |
| 18 | 23 | 7.4 | 43.30 | 11.0 | 4.76 |
| 19 | 41 | 6.4 | 49.70 | 17.0 | 8.45 |
| 20 | 30 | 6.8 | 46.80 | 8.0 | 3.74 |
| 21 | 20 | 6.7 | 34.56 | 13.0 | 4.49 |
| 22 | 25 | 7.0 | 40.10 | 8.0 | 3.21 |
| 23 | 21 | 7.8 | 41.70 | 16.0 | 6.67 |
| 24 | 21 | 8.0 | 46.96 | 10.0 | 4.70 |
| 25 | 24 | 9.0 | 63.46 | 8.0 | 5.08 |
| 26 | 25 | 9.2 | 68.96 | 15.0 | 10.34 |
| Average | 30 | 6.7 | 42.64 | 10.9 | 4.65 |

[a]Pulp values calculated at $2.50 per cord and 90 cu. ft. per cord.
[b]Mortality rates adapted from *Tree Condition and Mortality Following Defoliation by the Gypsy Moth* by Robert W. Campbell and Harry T. Valentine.

Average merchantable volume from Schnur's (7) volume tables $\approx$ 12 cu. ft./tree
Average number trees per plot = 30
Average number trees per acre = 300
Average merchantable volume at maturity:
300 trees x 12 cu. ft./tree = 3,600 cu. ft.

$$\frac{3{,}600 \text{ cu. ft.}}{90 \text{ cu. ft./cd.}} = 40 \text{ cd.}$$

Value at maturity:
40 cd. x $2.50/cd. = $100.00
Value loss due to gypsy moth:
Expected mortality rate due to one heavy defoliation = .109
$100.00 x .109 = $10.90 per acre
Discounted value: $\frac{\text{expected loss}}{(1+i)^n}$
Discounting period (n) = 50 years
Interest rate (i) = 5 percent

$$\frac{\$10.90}{11.4674} = \$0.95 \text{ per acre.}$$

Thus, for this particular example, $0.95 per acre is the amount that could prudently be spent on control measures if it eliminated all the expected mortality. It would give the same rate of return as putting the money in a bank at 5 percent compound interest.

If we knew the amount some control measure would cost per acre, and its effectiveness, we could determine what the rate of return would be if the control methods were applied. For instance, in this example, if the control method cost $10.90 per acre and were 100 percent effective, the rate of return would be zero. If $2.00 per acre were the cost of control, the rate of return would be determined as follows:

$$\frac{\$10.90}{\$2.00} = 5.4500$$

Looking up 5.4500 in compound interest tables for 50 years, we find the rate of return very close to 3.45 percent.

## Case Study III – Calculating Immediate Loss in a Sawtimber Stand

The immediate sawtimber losses were calculated in the same general way as immediate pulpwood losses, but the details of the calculation are different. To obtain a value estimate, we must estimate the quality of lumber that may be sawn from each tree. This may be done by using log grading techniques *(6)*. For our sawtimber examples, immediate and future, we used sawlog values developed by J. J. Mendel.[2] His sawlog values were calculated by subtracting from the estimated standing tree values for grade lumber all direct costs of converting the tree into lumber. For some trees the conversion cost was higher than the standing tree value, which resulted in some negative sawtimber values.

The immediate sawtimber value loss per sample plot in this case is $15.08. As these sample plots are 1/5 acre, this value multiplied by five represents the immediate loss per acre that may be expected from one year of heavy gypsy moth infestation ($15.08 x 5 = $75.40) (table 2).

[2]Joseph J. Mendel. Unpublished.

## Case Study IV – Calculating Future Loss in a Sawtimber Stand

Prediction of harvest value for a sawtimber stand requires consideration of volume, quality, and future value. Projecting sawtimber quality into the future is hazardous, but a recent study by McCay and DeBald (*5*) developed a method for projecting quality changes by using probabilities. The probabilities were based on the changes that had occurred in a sample area over the last 10 years (fig. 1).

Three projections were made—high, expected, and low. The high projections represent what the trees would be at harvest if all of them developed as did the upper 10 percent in the frequency distributions. The low projections use the lowest 10 percent. The expected projections used the median of the probability distributions.

Each tree in the sample plots was evaluated according to the following example:

*Present Characteristics*

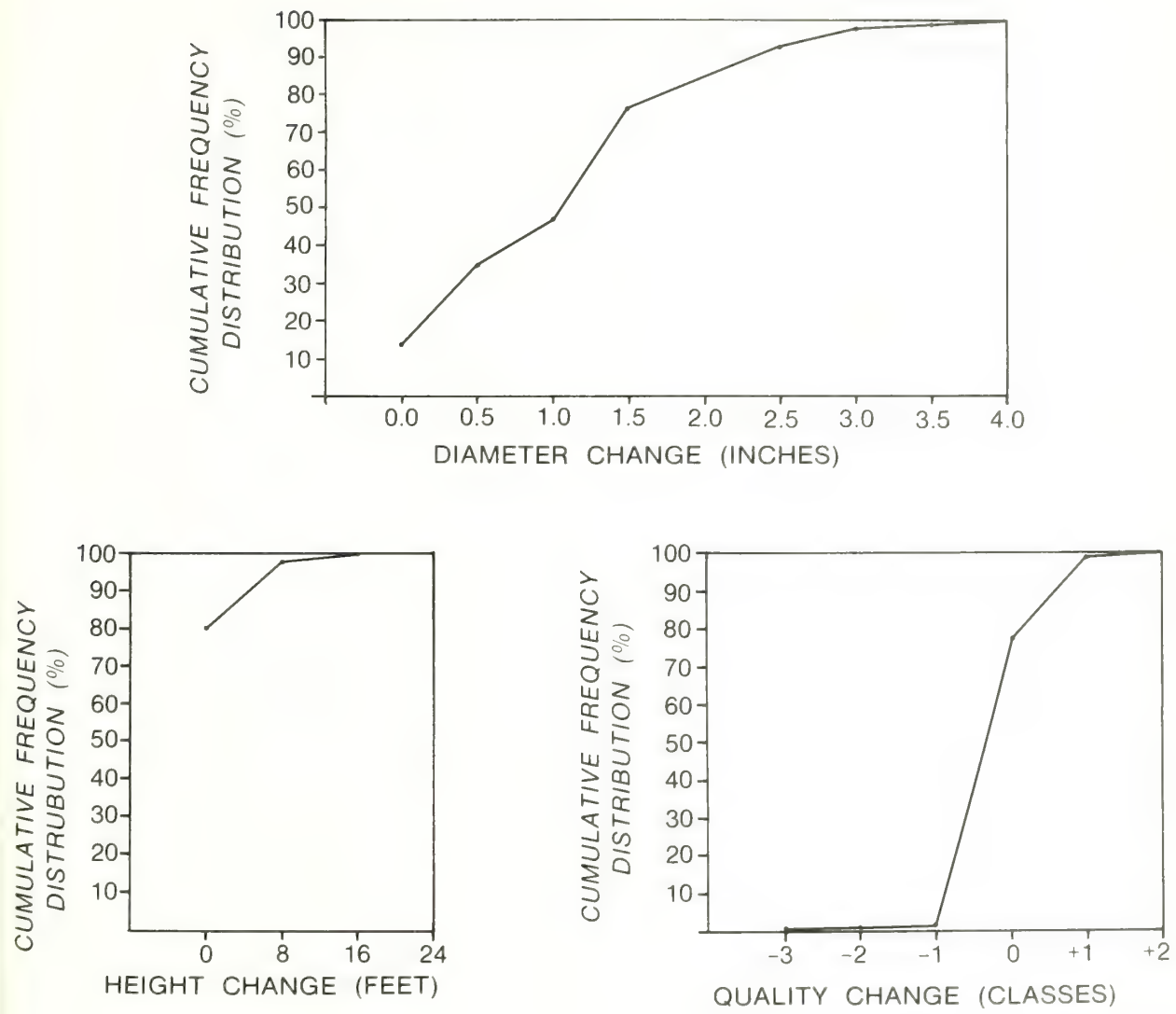
White oak
- Diameter breast high – 14.6 inches
- Merchantable height – 32 feet
- Butt log grade – 3

Table 2.—Sawtimber plot information

| Plot | Trees per plot (1/5 acre) | Average tree d.b.h. | Sawtimber value per acre[1] | Expected mortality loss[2] | Sawtimber value change per acre[3] |
|---|---|---|---|---|---|
| | *Number* | *Inches* | *Dollars* | *Percent* | *Dollars* |
| 1 | 16 | 14.9 | 835.00 | 34.6 | −288.90 |
| 2 | 12 | 13.4 | 10.50 | 33.8 | − 3.55 |
| 3 | 22 | 13.1 | 550.65 | 25.7 | −141.50 |
| 4 | 8 | 14.4 | −10.05 | 9.0 | + .90 |
| 5 | 13 | 11.4 | 144.50 | 26.0 | − 37.55 |
| 6 | 15 | 13.8 | 453.75 | 19.5 | − 88.50 |
| 7 | 17 | 18.7 | 387.80 | 29.3 | −113.65 |
| 8 | 16 | 13.4 | 214.40 | 13.1 | − 28.10 |
| 9 | 17 | 13.1 | 283.30 | 39.5 | −111.90 |
| 10 | 21 | 10.8 | 115.90 | 23.9 | − 27.70 |
| 11 | 28 | 9.7 | −43.85 | 25.1 | + 11.00 |
| Average | 17 | 13.3 | 267.44 | 28.0 | − 75.40 |

[1]Sawtimber values from J. J. Mendel's unpublished data, Columbus, Ohio. Negative value is due to conversion cost's being higher than value returned.
[2]Mortality losses adapted from *Tree Condition and Mortality Following Defoliation by the Gypsy Moth* by Robert W. Campbell and Harry T. Valentine.
[3]Two plots increased in value due to losing trees that had negative values.

Figure 1.—Probability of changes in sawtimber tree characteristics.




From figure 1 the low projection would have no change in d.b.h., no change in height, and no change in quality. The high projection would increase d.b.h. by 2.5 inches, increase height by 8 feet, and increase quality by 1 class. The projections for this tree could be summarized as follows:

| | *Present Characteristics* | | |
|---|---|---|---|
| | *D.b.h. (inches)* | *Height (feet)* | *B.l.g.* |
| Low | 14.6 | 32 | 3 |
| Expected | 16.1 | 32 | 3 |
| High | 17.1 | 40 | 2 |

Once the projected tree characteristics were determined tree values were applied and multiplied by the expected mortality (values were held constant for the entire time frame). The result is the loss that might be caused by the gypsy moth. The plot values were summed, averaged, and converted to a per-acre basis (table 3). The per-acre values were discounted to determine the value loss in terms of today's dollars (table 4). The discounting period was 10 years because this stand would reach maturity in that time.

Table 3.—Future sawtimber loss per acre

| Projection | Value before gypsy moth | Value after gypsy moth | Dollar loss due to gypsy moth |
|---|---|---|---|
| Low | $294.15 | $218.75 | $ 75.40 |
| Expected | 399.60 | 284.50 | 115.10 |
| High | 652.60 | 457.55 | 195.05 |

Table 4.—Future sawtimber losses per acre, discounted over 10 years

| Projection | Discounting rate | | |
|---|---|---|---|
| | 3% | 5% | 7% |
| Low | $\frac{75.40}{1.34392} = \$ 56.10$ | $\frac{75.40}{1.62889} = \$ 46.29$ | $\frac{75.40}{1.96715} = \$ 38.33$ |
| Expected | $\frac{115.10}{1.34392} = \$ 85.64$ | $\frac{115.10}{1.62889} = \$ 70.66$ | $\frac{115.10}{1.96715} = \$ 58.51$ |
| High | $\frac{195.05}{1.34392} = \$145.14$ | $\frac{195.05}{1.62889} = \$119.74$ | $\frac{195.05}{1.96715} = \$ 99.15$ |

## Impact of Gypsy Moth on Forest Management Opportunities

As mentioned earlier, a forest may suffer losses in one or more forms. One form of loss is the restriction of forest management alternatives.

Forest management altrnatives are the choices of techniques by which young stands are manipulated to produce mature stands ready for harvest. As a stand grows toward maturity various timber management alternatives are available to the forest manager. The choice depends on the stand characteristics at a given time. One guide for timber management decisions developed by Gingrich (*4*) is based on stocking percentage. He classifies the stocking level as follows: below understocked = less than 42 percent stocked; understocked = 42 percent to 58 percent stocked; fully stocked = 58 percent to 100 percent stocked; and overstocked = more than 100 percent stocked.

After one year of heavy gypsy moth defoliation, the stocking level remained in the same class for 77 percent of the pulpwood plots (table 5). Twenty-two of the 26 plots were in the class that fully utilized the site. Therefore,

Table 5.—Pulpwood management loss

| Plot | Stocking percentage | |
|---|---|---|
| | Before gypsy moth | After gypsy moth |
| 1 | 97 | 74 |
| 2 | 88 | 81 |
| 3 | 51 | 47 |
| 4 | 86 | 76 |
| 5 | 98 | 85 |
| 6 | 80 | 73 |
| 7 | 72 | 66 |
| 8 | 75 | 69 |
| 9 | 62 | 55 |
| 10 | 55 | 48 |
| 11 | 68 | 62 |
| 12 | 98 | 91 |
| 13 | 80 | 75 |
| 14 | 70 | 62 |
| 15 | 108 | 88 |
| 16 | 108 | 93 |
| 17 | 102 | 85 |
| 18 | 88 | 73 |
| 19 | 110 | 92 |
| 20 | 88 | 82 |
| 21 | 61 | 54 |
| 22 | 75 | 62 |
| 23 | 73 | 61 |
| 24 | 77 | 70 |
| 25 | 98 | 92 |
| 26 | 112 | 95 |
| Average | 84 | 74 |

we could still manage the area for timber production without destroying the existing stand and starting a new one. Our loss is the value of merchantable pulpwood from any proposed thinning operation. The value of the pulpwood loss has been discussed earlier and management flexibility is not an issue.

Examination of the sawtimber-size stands reveals that four of eleven plots drop from understocked or better to below understocked after one year of heavy gypsy moth defoliation (table 6). (One plot is below understocked before defoliation.) The management recommendation for areas below the understocked level is to clearcut and regenerate a new stand. Before this is done, we should consider other factors such as location of understocked plots, market conditions, condition of remaining timber, value of stand as wildlife habitat, etc.

Table 6.—Sawtimber management loss

| Plot | Stocking percentage | |
|---|---|---|
| | Before gypsy moth | After gypsy moth |
| 1 | 82 | 48 |
| 2 | 57 | 35 |
| 3 | 88 | 40 |
| 4 | 40 | 25 |
| 5 | 42 | 30 |
| 6 | 68 | 46 |
| 7 | 120 | 82 |
| 8 | 69 | 50 |
| 9 | 71 | 48 |
| 10 | 62 | 38 |
| 11 | 68 | 48 |
| Average | 70 | 45 |

The average plot information indicates that on the other plots the stocking level drops from fully stocked to understocked after the defoliation. Assuming no subsequent defoliations, these stands should reach fully stocked in 10 years. Therefore, the gypsy moth has performed a thinning operation at a cost equal to the value of the trees that might have been marketed. The procedure for estimating the value of this loss has been discussed earlier.

# DISCUSSION

Because the forests are used for many things, we must consider more than wood production when trying to establish the value loss caused by the gypsy moth. The importance of the other uses will vary with the individual forest, the type of damage and control measures, and the people setting priorities for the forest. A format for listing and evaluating forest uses and alternative control measures has been developed (table 7). More items of concern and new control measures may be added to assure a complete evaluation for a local forest.

The following abbreviated example indicates how the table may be interpreted. (The values used are hypothetical.)

| | *Do nothing* | *A* |
|---|---|---|
| Probability of success | 5% | 98% |
| Cost | $0 | $8/acre |
| Air quality | No effect | Effect |
| Water quality | No effect | Effect |
| Soil | No effect | Effect |
| Resource values | Lose $80/acre | Lose $2/acre |
| Federal | – | Banned |

Control measure A was the application of DDT and if we ignored the federal ban and were willing to accept any consequences to the soil and water, then DDT is a feasible alternative when compared to the do-nothing alternative. But DDT is banned, which eliminates it from consideration, and the do-nothing alternative may then be compared with other alternative control measures.

# SUMMARY

Basic information required for an economic evaluation of the effect of defoliation on trees is time frame, damage caused, and values. Time frame establishes whether we are dealing with the present or the future. Direct calculations can be made for the present; calculations for the future require some predictions about

Table 7.—Format for evaluating the impact of alternative gypsy moth control measures

| Item of concern | Do Nothing | Alternative control measures A | B | C | D | E |
|---|---|---|---|---|---|---|
| 1. Program factors | | | | | | |
| Prob. of success | | | | | | |
| Cost | | | | | | |
| 2. Environmental factors | | | | | | |
| Air quality | | | | | | |
| Water quality | | | | | | |
| Soil | | | | | | |
| Temp. & humidity | | | | | | |
| Noise | | | | | | |
| Flora & fauna | | | | | | |
| 3. Socio-Economic factors | | | | | | |
| Resource values | | | | | | |
| Access | | | | | | |
| Ethnic & cultural values | | | | | | |
| Ownership responsibility | | | | | | |
| Management alternatives | | | | | | |
| 4. Political | | | | | | |
| Local | | | | | | |
| State | | | | | | |
| Federal | | | | | | |

changes that may occur during the time before harvest. These changes involve growth rates, quality measures, interest rates, price variations, mortality estimates, etc.

The damage caused by the defoliation determines how great any loss will be. Some trees are lost because of one heavy defoliation.

Applying economics to a problem requires some measure of value. Trees have many values to various people; these values must be defined and measured before they can be used.

These principles were applied to a pulpwood and a sawtimber stand subjected to one year of heavy gypsy moth infestation. For these examples, the final loss values represent what a prudent owner could spend to protect his forested area from one heavy gypsy moth defoliation. All the dollar values presented in our sample calculations are not recommended for other forested areas; conditions, markets, prices, and objectives may be different. We suggest that you use proper methods to arrive at values for your area.

Another factor for consideration is the effect of defoliation on forest management alternatives. Our example was based on stocking percentage. The sample analysis indicates no change in alternatives for the pulpwood stand. The sawtimber stand changes from fully stocked before defoliation to understocked after defoliation.

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by William T. Plass
and Willis G. Vogel

# Chemical Properties and Particle-Size Distribution of 39 SURFACE-MINE SPOILS in Southern West Virginia

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6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

WILLIAM T. PLASS received a B.S. degree in forestry from Iowa State University in 1948, and an M.S. degree in silviculture from the University of Missouri in 1959. He joined the U.S. Forest Service in 1948, and has served in several capacities in projects relating to timber management and the silviculture of central hardwoods. Since 1962 he has been assigned to the surface mine restoration project. He is now assigned to this project's field office located at the Forest Products Marketing Laboratory at Princeton, West Virginia.

WILLIS G. VOGEL, range scientist, received a B.S. degree in agriculture in 1952 from the University of Nebraska and an M.S. degree in range management in 1961 from Montana State University. He was employed in 1959 as a range conservationist with the USDA Soil Conservation Service in Idaho. In 1960 he joined the U.S. Forest Service as a research range conservationist in southwest Missouri and transferred in 1963 to the Northeastern Forest Experiment Station's strip mine restoration project at Berea, Kentucky.

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# Chemical Properties and Particle-Size Distribution of 39 SURFACE-MINE SPOILS in Southern West Virginia


## ABSTRACT

A survey of 39 surface-mine sites in southern West Virginia showed that most of the spoils from current mining operations had a pH of 5.0 or higher. Soil-size material averaged 37 percent of the weight of the spoils sampled. A major problem for the establishment of vegetation was a deficiency of nitrogen and phosphorus. This can be corrected with additions of fertilizer at appropriate rates.


THE CHEMICAL COMPOSITION of the geologic materials blended together in surface-mine spoils affects vegetation establishment and growth. It may also alter the chemistry of surface and subsurface waters flowing from disturbed areas. Success of revegetation and water quality may also be influenced by the particle-size distribution of the spoil material.

An examination of spoils associated with some of the more important southern West Virginia coal seams permits an assessment of the opportunities for successful vegetation establishment and the probability of surface mining affecting the chemistry of associated streams.

It is assumed that wide variation does exist among spoil materials. The West Virginia Geologic and Economic Survey has identified 62 minable coal beds within the state. These are distributed through a stratigraphic column that may be as much as 6,750 feet thick. In all probability, there were wide variations in the paleo-environment when each of these coal seams was laid down. Even greater environmental variations could have occurred as the various rock strata above the coal seam were formed. Therefore, when these widely differing

geologic materials are disturbed, mixed, and exposed by mining to weathering processes, we can expect variations in the chemical composition and particle-size distribution of spoil material from different coal seams.

In this study, we collected sample material from 39 locations in the southern West Virginia coal field. These were analyzed in a laboratory and greenhouse to identify properties that may affect establishment of vegetation.

Table 1.—Original reserves of coal seams selected for study

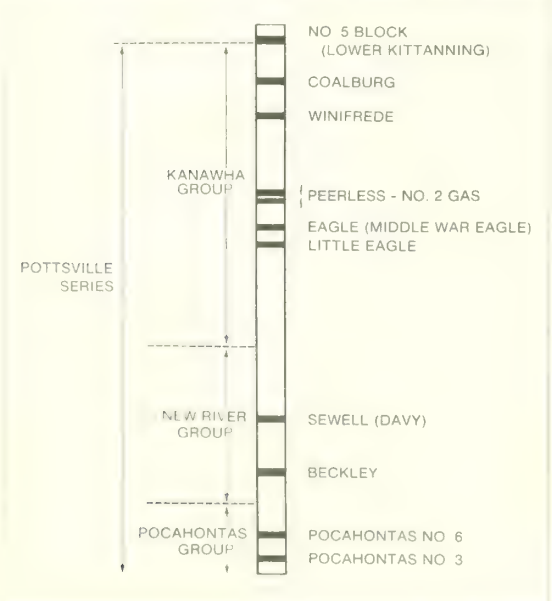
| Coal seam | Original reserves |
|---|---|
| | *Million tons* |
| No. 5 Block | 10.3 |
| Coalburg | 3.4 |
| Winifrede | 3.5 |
| Peerless and No. 2 Gas | 9.9 |
| Eagle | 4.2 |
| Little Eagle | .9 |
| Sewell | 6.3 |
| Beckley | 2.0 |
| Pocahontas No. 6 | .9 |
| Pocahontas No. 3 | 2.9 |
| Total | 44.3 |

# THE STUDY

In cooperation with the West Virginia Department of Natural Resources, the West Virginia Surface Mining and Reclamation Association, and others, we selected 10 coal seams for study (fig. 1). All are believed to have extensive acreage of disturbance and large reserves that could be recovered by surface mining methods. The Peerless and No. 2 Gas seams were considered as one seam because the interval between them is small, and the spoils often mix.

The sample included coal seams from the base of the Pennsylvanian period through the entire Pottsville series to the No. 5 Block or Lower Kittanning coal bed at the base of the Allegheny series (table 1). Forty-four coal seams are recognized within this geologic section. The original reserves for these beds were estimated to be 79.5 billion tons.[1] More than 50 percent of this total is accounted for in reserves in the coal seams selected for this study.

Figure 1.—Stratigraphic section, showing relative positions of coal seams sampled.




## Field Sampling

Four sample locations, widely separated geographically, were selected for all coal seams except the combined Peerless and No. 2 Gas, for which three locations were used. The spoil at each location was 6 months or less in age, regraded but not seeded or fertilized, and mined by a different operator. Sampling began in the fall of 1969 and was completed in November 1970.

At each location we selected a sampling point that appeared to be representative of most of the spoil. This decision was based on surface characteristics such as color, the proportion of sandstone and shale, and the size of the rock fragments.

All samples were collected along a 100-foot base line located on the outside edge of the bench at the crest of the outslope. The following samples were collected from the surface 6 inches at points evenly spaced along this base line:

[1]Tucker, R. C. BITUMINOUS COAL BEDS IN WEST VIRGINIA. West Virginia Geological Survey, Columnar Section. 1939.

1. Ten samples weighing 1 pound each. Rock fragments larger than ½ inch were removed from this material.
2. Three samples weighing 5 pounds each. These samples included rock fragments weighing a pound or less as they occurred on the spoil surface. We did not attempt to measure the percentage of the total spoil volume or weight of rock fragments heavier than a pound.
3. Approximately 60 pounds of material from one point at 25 of the locations. This material, passed through a screen with a ½-inch mesh, was used for the greenhouse tests. These collections were made at three locations on the Pocahontas No. 3, Pocahontas No. 6, Beckley, Winifrede, and Coalburg coal seams; and at two locations on the Little Eagle, No. 5 Block, Sewell, Eagle and Peerless—No. 2 Gas coal seams.

## Laboratory Procedures

We determined pH and available phosphorus for each of the ten 1-pound samples. Available phosphorus was determind with the Bray No. 1 extractant solution. The pH was determined with a pH meter on a 1:2 mixture of spoil and distilled water.

Material from the three 5-pound samples was screened to obtain the percentage by weight of various sizes of rock and soil. This material was air-dried, then sieved through screens with ¾-inch, ½-inch, ¼-inch, and 2 mm. mesh. Chemical analyses of the material passing the 2 mm. mesh were made to determine exchangeable acidity, exchangeable aluminum, and exchangeable hydrogen. The titration method developed by Yuan[2] was used for these determinations.

Laboratory analyses showed that the spoil collected for greenhouse use was chemically and physically similar to the 1- and 5-pound samples of spoil.

## Greenhouse Tests

The relative productivity of the spoils collected from the 25 locations was compared by growing Kentucky-31 tall fescue *(Festuca arundinacea)* and sericea lespedeza *(Lespedeza cuneata)* in pots of the spoil in the greenhouse. The following fertility treatments were applied to the spoils:

*Kentucky-31 fescue*:

1. Check (no fertilizer).
2. Nitrogen: 50 p.p.m. or 100 pounds N per acre.
3. Phosphate: 22 p.p.m. P or 100 pounds $P_2O_5$ per acre.
4. Nitrogen plus phosphate: at rates used in (2) and (3).
5. Nitrogen, phosphate, and potassium: nitrogen and phosphate at rates used in treatments (2) and (3), and potassium at a rate of 42 p.p.m. K or 100 pounds $K_2O$ per acre.

*Sericea lespedeza*:

1. Check (no fertilizer).
2. Phosphate: 22 p.p.m. P or 100 pounds $P_2O_5$ per acre.
3. Nitrogen plus phosphate: nitrogen at a rate of 20 p.p.m. or 40 pounds per acre, and phosphate at rates used in treatment (2).
4. Nitrogen, phosphate, and potassium: nitrogen and phosphate at rates used in treatments (2) and (3), and potassium at a rate of 42 p.p.m. K or 100 pounds $K_2O$ per acre.

The fertilizer materials used for supplying the N, P, and K were respectively ammonium nitrate, monobasic calcium phosphate, and potassium chloride. Treatments were not replicated within each spoil collection.

An error in procedure eliminated the intended nitrogen treatment for sericea lespedeza.

Each treatment was applied to two pots containing 2,000 grams of air-dried spoil. Fescue was seeded in one pot, and sericea lespedeza in the other. Distilled water was added to bring the spoil moisture content up to field capacity and maintain it there. The fescue was grown for 44 days from seeding to harvest; and the lespedeza 77 days. At the termination of each test, the plants were clipped at ground line, oven-dried, and weighed to determine yield.

[2]Yuan, T. L. DETERMINATION OF EXCHANGEABLE HYDROGEN IN SOILS BY A TITRATION METHOD. Soil Science 88: 164-167. 1959.

# RESULTS

## Particle-Size Distribution

The primary interest in this analysis was the percentage, by weight, of particles 2 mm. or less in size—the soil-size fraction. This portion affects water retention and availability, which in turn relates to plant establishment and growth. The potential for chemical pollution through weathering and soil erodibility are also related to the percentage of soil-size material on the spoil surface.

We found no significant statistical differences among coal seams in the percentage of soil-size particles per sample (table 2). The wide variation among samples for each coal seam apparently obscures any significant differences among coal seams.

The soil-size fraction for all spoils averaged 37 percent of the total air-dried weight. Material passing a ¼-inch mesh screen accounted for 60 percent of the sample weight.

Apparently spoils in the southern West Virginia coal field have sufficient soil-size material to retain adequate amounts of water during normal weather conditions. The percentage of material passing a 2-mm sieve is less for the essentially unweathered spoil material than for the intensively weathered natural soils occurring above and below the mining disturbance. As an example, the percentage of material less than 2 mm. in size in three natural soils that occur over large acreages in southern West Virginia are as follows: Dekalb soils, 65-95 percent; Gilpin soils, 35-80 percent; and Muskingum soils, 65-95 percent.[3] By comparison, the material 2 mm. or less in the spoils sampled ranged from 17 to 64 percent. This percentage is expected to increase rapidly as weathering breaks down the large particles.

The proportion of soil-size material indicates that these spoils may be more vulnerable to the forces of erosion than coarser spoils. These small particles also provide a large surface area for chemical reaction and weathering.

## Spoil pH and Available Phosphorus

The ten 1-pound samples collected at each site were analyzed for pH and available phos-

[3]Soil Survey, Fayette and Raleigh Counties, West Virginia. Unpublished manuscript, Soil Conservation Service.

Table 2.—Particle size distribution by coal seam in percent

| Coal seam | | Particle size | | | | |
|---|---|---|---|---|---|---|
| | | <2mm. | <¼ inch > 2 mm. | <½ inch >¼ inch | <¾ inch >½inch | >¾ inch |
| Pocahontas No. 3 | Mean | 33.5 | 21.8 | 14.3 | 9.3 | 21.1 |
| | Standard Deviation | 7.8 | 2.6 | 2.7 | 1.9 | 8.4 |
| Pocahontas No. 6 | Mean | 33.6 | 24.0 | 14.8 | 10.9 | 16.7 |
| | Standard Deviation | 5.0 | 4.3 | 5.3 | 2.0 | 7.4 |
| Beckley | Mean | 41.8 | 21.7 | 12.1 | 8.5 | 15.9 |
| | Standard Deviation | 6.6 | 4.9 | 2.0 | 1.8 | 9.0 |
| Sewell | Mean | 40.1 | 22.9 | 12.6 | 8.7 | 15.7 |
| | Standard Deviation | 9.4 | 3.7 | 2.7 | 2.9 | 6.6 |
| Little Eagle | Mean | 36.7 | 24.0 | 15.7 | 9.3 | 14.3 |
| | Standard Deviation | 10.2 | 3.5 | 3.8 | 3.1 | 8.1 |
| Eagle | Mean | 35.9 | 24.3 | 14.1 | 9.6 | 16.1 |
| | Standard Deviation | 8.4 | 3.5 | 4.9 | 2.0 | 6.0 |
| Peerless-No. 2 Gas | Mean | 41.8 | 23.5 | 14.6 | 8.6 | 11.5 |
| | Standard Deviation | 9.5 | 5.4 | 3.8 | 2.1 | 6.1 |
| Winifrede | Mean | 32.9 | 23.4 | 13.7 | 10.1 | 19.9 |
| | Standard Deviation | 13.0 | 6.4 | 4.3 | 3.8 | 14.7 |
| Coalburg | Mean | 37.0 | 20.3 | 14.7 | 12.4 | 15.6 |
| | Standard Deviation | 5.9 | 4.0 | 5.1 | 4.5 | 6.0 |
| No. 5 Block | Mean | 40.9 | 19.9 | 14.5 | 8.3 | 16.4 |
| | Standard Deviation | 11.3 | 1.9 | 2.8 | 2.7 | 7.5 |
| Mean, all samples | — | 37.2 | 22.6 | 14.1 | 9.6 | 16.5 |

Table 3.—Spoil pH by coal seam

| Coal seam | Median | Standard Deviation | Distribution | | | |
|---|---|---|---|---|---|---|
| | | | pH 6.1+ | pH 5.1—6.0 | pH 4.1—5.0 | pH 4.0 or less |
| | | | *Percent of samples* | | | |
| Pocahontas No. 6 | 5.7 | 0.30 | 13 | 87 | 0 | 0 |
| Pocahontas No. 3 | 5.6 | .32 | 3 | 94 | 3 | 0 |
| Beckley | 5.3 | .77 | 33 | 42 | 22 | 3 |
| Little Eagle | 5.2 | .68 | 27 | 53 | 20 | 0 |
| Winifrede | 5.1 | 1.24 | 33 | 37 | 30 | 0 |
| No. 5 Block | 5.1 | .76 | 33 | 32 | 35 | 0 |
| Coalburg | 5.0 | .39 | 3 | 45 | 52 | 0 |
| Sewell | 5.0 | .64 | 27 | 36 | 32 | 5 |
| Eagle | 4.5 | 1.14 | 27 | 33 | 10 | 30 |
| Peerless-No. 2 Gas | 4.5 | .44 | 0 | 7 | 80 | 13 |
| Mean, all samples | — | — | 20 | 48 | 27 | 5 |

phorus. These data showed significant differences among coal seams for both variables (table 3). All seams except the Eagle and Peerless-No. 2 Gas had a median pH of 5.0 or more, indicating that most of the plant species commonly used for reclaiming strip mines can be grown successfully. By comparison, natural soils commonly occurring above or below the mining disturbance are often classified as very strongly acid or strongly acid. This means that the pH of the natural soils may vary from 4.5 to 5.5

Very low phosphorus (<3.0 p.p.m. P) occurred in spoils of the No. 5 Block, Little Eagle, Winifrede, and Coalburg seams. Spoils of all of the other seams except Pocahontas No. 6 were low (3.1 to 7.0 p.p.m. P) in available phosphorus (table 4). This indicates that most of the spoils in southern West Virginia will probably have insufficient phosphorus for the rapid establishment and good growth of seeded vegetation.

The data indicate that spoil acidity is not a major problem in the southern West Virginia coal field. Samples with a pH of 4.0 or less (extremely acid) occurred on only four coal seams, and they were a relatively small portion of the total samples. Extremely acid spoil was most common on the Eagle seam, but also occurred on the Peerless-No. 2 Gas, Sewell, and Beckley seams. Acid pollution from spoils may occur where these seams were mined. Care must be exercised in mining and regrading operations on these coal seams to insure that acid-forming materials are segregated and buried.

Table 4.—Available phosphorus by coal seam

| Coal seam | Mean | Distribution | | |
|---|---|---|---|---|
| | | Very low 0.1—3.0 p.p.m. | Low 3.1—7.0 p.p.m. | Medium 7.1—20.0 p.p.m. |
| | *p.p.m.* | *Percent* | | |
| Pocahontas No. 6 | 8.0 | 3 | 34 | 63 |
| Peerless-No. 2 Gas | 5.0 | 33 | 37 | 30 |
| Sewell | 4.9 | 55 | 25 | 20 |
| Pocahontas No. 3 | 3.6 | 23 | 74 | 3 |
| Eagle | 3.2 | 53 | 42 | 5 |
| Beckley | 3.2 | 55 | 35 | 10 |
| No. 5 Block | 2.8 | 60 | 37 | 3 |
| Little Eagle | 2.5 | 63 | 37 | 0 |
| Winifrede | 2.4 | 80 | 20 | 0 |
| Coalburg | 1.8 | 92 | 8 | 0 |
| Mean, all samples | — | 52 | 35 | 13 |

Sixty-eight percent of the samples had a pH above 5.0, but 87 percent of the samples tested below a medium level (7p.p.m.) of phosphorus. Therefore deficiencies in plant nutrients, especially plant-available phosphorus, probably contribute to the failure and slow growth of seeded grasses and legumes more than does high acidity. Fortunately this condition can be corrected easily with phosphate fertilizers.

### Exchangeable Acidity, Aluminum, and Hydrogen

Three samples of the soil-size fraction from each location were used for this analysis. Each sample was analyzed to determine exchangeable acidity, exchangeable aluminum, and exhangeable hydrogen. The latter two elements account for most of the exchangeable acidity that was present in these spoils. Our objective was to use these measures to identify spoils that may be difficult to revegetate. Exchangeable acidity is also used for determining rates of lime that are required to neutralize the acidity present in spoils.

Values for exchangeable acidity ranged from 0.05 to 14.35 meq./100 g. There were significant differences among spoils of the various coal seams. There was also much variation in acidity among samples of individual coal seams. The Sewell and Eagle spoils had the highest level of exchangeable acidity. Means for these spoils were 3.45 and 3.40 meq./100 g. The lowest values occurred on the Pocahontas No. 3 and No. 6 spoils (table 5).

Exchangeable aluminum ranged from 0 to 7.25 meq./100 g. There were significant differences among spoils. High values occurred in the No. 5 Block and Sewell spoils. Low values occurred in the Pocahontas No. 3 and No. 6 spoils.

From these analyses, spoils from the Pocahontas No. 3, Pocahontas No. 6, Beckley, and Little Eagle coal seams could be expected to have low exchangeable acidity and aluminum, and generally would present few or no problems in establishing vegetation. The Sewell, Eagle, Peerless-No. 2 Gas, Coalburg, and No. 5 Block coal seams have spoils with the highest exchangeable acidity and aluminum. The higher levels of acidity and aluminum in these spoils can cause problems in establishing seeded grasses and legumes.

Evidence from other research indicates that wide variation can occur in the properties of the various rock strata in the overburden above the coal seam. If the strata contributing excessive acidity and aluminum could be identified, then mining and regrading methods could be modified so that this acid material would be buried. The material most suitable for plant growth would be exposed on the spoil surface.

The chemical composition of the Eagle spoils was the most variable. The pH ranged from 2.9 to 6.5, available phosphorus from 1.4 to 17.5 p.p.m., exchangeable acidity from 0.05 to 14.35 meq./100 g., and exchangeable aluminum from 0 to 7.25 meq./100 g. This reflects the differences in the chemical composition of the various rock strata above the coal seam. It also shows the revegetation problems that can

Table 5.—Mean values for pH and for exchangeable acidity, aluminum, and hydrogen

| Coal seam | Median pH | Exchangeable Acidity | Exchangeable Aluminum | Exchangeable Hydrogen |
|---|---|---|---|---|
| | | *meq./100g.* | | |
| Pocahontas No. 6 | 5.7 | 0.44 | 0.29 | 0.15 |
| Pocahontas No. 3 | 5.6 | .51 | .34 | .17 |
| Beckley | 5.3 | 1.03 | .73 | .30 |
| Little Eagle | 5.2 | .88 | .63 | .25 |
| No. 5 Block | 5.1 | 2.91 | 2.44 | .47 |
| Winifrede | 5.1 | 1.41 | 1.16 | .25 |
| Coalburg | 5.0 | 2.22 | 1.77 | .45 |
| Sewell | 5.0 | 3.45 | 2.44 | 1.01 |
| Eagle | 4.5 | 3.40 | 1.92 | 1.48 |
| Peerless-No. 2 Gas | 4.5 | 2.48 | 2.04 | .44 |

be caused on spoils derived from overburden of such composition.

## Vegetation Response to Fertilizer

In the greenhouse evaluation of vegetation response to fertilization, the yields of plants in each fertilizer treatment were compared with yields of plants without fertilizer. The 25 spoils used in this test included two or three samples from each of the ten coal seams. However, the results presented here emphasize the overall response of plants to fertilizer treatments and spoil chemical properties. Relating plant response to individual coal seams is less meaningful because of the wide variation in spoil properties that can occur even on one seam.

Highest yields of both K-31 fescue and sericea lespedeza occurred on the spoils fertilized with nitrogen plus phosphorus. The addition of potassium did not increase yields (table 6). In fact, the addition of potassium fertilizer caused more reductions than increases in yield, especially with the sericea lespedeza. This indicates that potassium is not deficient in these spoils, and application of potassium fertilizer normally would not be required.

Fertilizing with both nitrogen and phosphorus is essential for acceptable establishment and growth of K-31 fescue (fig. 2). This requirement also applies to other cool-season grasses normally used for vegetating mine spoils.

Fertilizing with both nitrogen and phosphorus also gave best yields of sericea lespedeza. However, fertilizing with phosphorus alone also gave substantial increases in yield (table 6 and fig. 3). This is because legumes such as sericea lespedeza, when inoculated with the proper nitrogen-fixing bacteria (*Rhizobia*) are capable of providing their own nitrogen. It is also the reason why legumes are considered as an important constituent of a plant mixture for vegetating strip-mine spoils.

The greenhouse tests also showed that yields of fertilized K-31 fescue were much lower on spoils that had a pH below 5.0 than

Figure 2.—A typical response of Kentucky-31 fescue to the fertilization treatments on spoil with pH above 5.0. This is a Coalburg spoil.

Figure 3.—A typical response of sericea lespedeza to the fertilizer treatments on spoil with pH above 5.0. This is a Pocahontas No. 6 spoil.

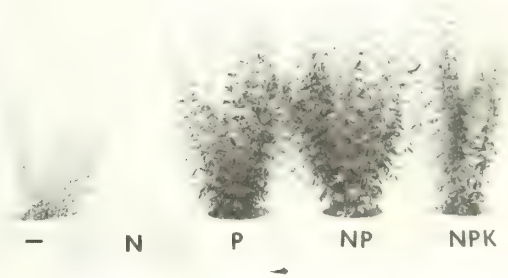



Table 6.—Average herbage yields of K-31 fescue and sericea lespedeza grown on spoils with several fertilizer treatments

| Spoil pH | Control | Fertilizer treatment N | P | NP | NPK |
|---|---|---|---|---|---|
| | | *grams/pot* | | | |
| | | K-31 FESCUE | | | |
| 3.9—4.5 | 0.2 | 0.6 | 0.4 | 1.3 | 1.1 |
| 4.6—5.0 | .2 | .4 | .5 | 1.6 | 1.2 |
| 5.1 and above | .4 | .9 | .8 | 3.9 | 3.6 |
| | | SERICEA LESPEDEZA | | | |
| 3.9—4.5 | .4 | — | .9 | 2.3 | .7 |
| 4.6—5.0 | 3.0 | — | 6.9 | 9.2 | 7.2 |
| 5.1 and above | 1.7 | — | 11.0 | 13.8 | 9.8 |

on spoils with a pH above 5.0 (table 6). If applied directly to field conditions, these results indicate that some problems may be encountered in establishing an adequate cover of fescue on spoils with a pH below 5.0. However, follow-up field trials should be made to determine the validity of these results for field conditions.

Yields of sericea lespedeza were much lower on spoils that had a pH below 4.5 than on spoils with pH above 4.5. Yields on spoils in the pH range 4.6 to 5.0 were only slightly lower than on spoils with pH above 5.0. These results suggest that sericea lespedeza can tolerate slightly more acid conditions than can K-31 fescue.

## CONCLUSIONS

This survey provided a reasonably optimistic outlook for the opportunities to successfully establish vegetation on surface-mine spoils in southern West Virginia. The pH of a majority of the spoils sampled is 5.0 or higher, and there seems to be enough soil-size material to retain sufficient moisture for satisfactory plant growth during normal weather conditions.

A major problem is a deficiency of essential plant nutrients. In greenhouse tests, the addition of nitrogen and phosphorus resulted in dramatic increases in plant growth on a majority of the sample spoils. Low pH and high exchangeable acidity and aluminum could have a detrimental effect on vegetation establishment on some spoils associated with the Sewell, Beckley, Peerless-No. 2 Gas, and No. 5 Block coal seams.

It is recognized that these results apply to spoils resulting from present-day mining and regrading methods. In some cases, the systematic placement during mining of certain strata in the overburden could result in a more productive spoil. To accomplish this, acidity tests would have to be made of each major strata in the overburden. Those strata identified as high in acidity could, where possible, be segregated and buried under better spoil, thus reducing the percentage of vegetation failures.

■

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Reliable Results from

# STOCHASTIC SIMULATION MODELS

**by Donald L. Gochenour, Jr.**
**Leonard R. Johnson**

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6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

U 518

## The Authors

DONALD L. GOCHENOUR, JR., an assistant professor in industrial engineering at West Virginia University, received his Ph.D. from that institution, in 1972. He also received his B.S. and M.S. degrees in industrial engineering from West Virginia University and worked for the engineering work unit in Morgantown, NEFES, as a research industrial engineer from 1967 to 1968.

LEONARD R. JOHNSON works as a research industrial engineer with the Northeastern Forest Experiment Station, engineering work unit, Morgantown, W. Va. He graduated in 1968 from Montana State University with a B.S. degree in industrial engineering and received an M.S. degree from Montana State University in 1970.

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# Reliable Results from

# STOCHASTIC SIMULATION MODELS


## ABSTRACT

Development of a computer simulation model is usually done without fully considering how long the model should run (e.g. computer time) before the results are reliable.

However construction of confidence intervals (CI) about critical output parameters from the simulation model makes it possible to determine the point where model results are reliable. If the results are not reliable, due to the variability within the model, the model user at least knows the degree of confidence that may be placed in the results.

Such factors as: 1) model variability, 2) prescribed width of the CI, and 3) the level of confidence of the simulation model results, have a profound effect on the amount of computer time needed to obtain reliable results. Since proper choice of these parameters can significantly affect the time and cost needed to obtain the results from the model, it is imperative that the user of the model consider these factors.

COMPUTER SIMULATION models of existing or hypothesized systems are often developed to obtain information about one or more system parameters. The simulation model provides the analyst with a tool for generating values of the system variables under study. However, the results obtained from stochastic simulation models are subject to the same questions of statistical reliability — precision of parameter estimates — as results of any other experiment. The analyst needs to know the statistical reliability of the results (*Reese 1968*) since accepting an unreliable estimate, because the simulation experiment was terminated too soon, could be costly when results are applied. Conversely, further computations after the results are reliable are unnecessary and wasteful.

The precision of estimates obtained from a simulation model depends on the length of the stochastic simulation run in the same way that the precision of a real-life experiment depends on the sample size. Failure to consider the precision of estimate may cause premature termination of the simulation experiment, resulting in unreliable parameter estimates or estimates no more reliable than those found by intuition or past experience in less time and at lower cost.

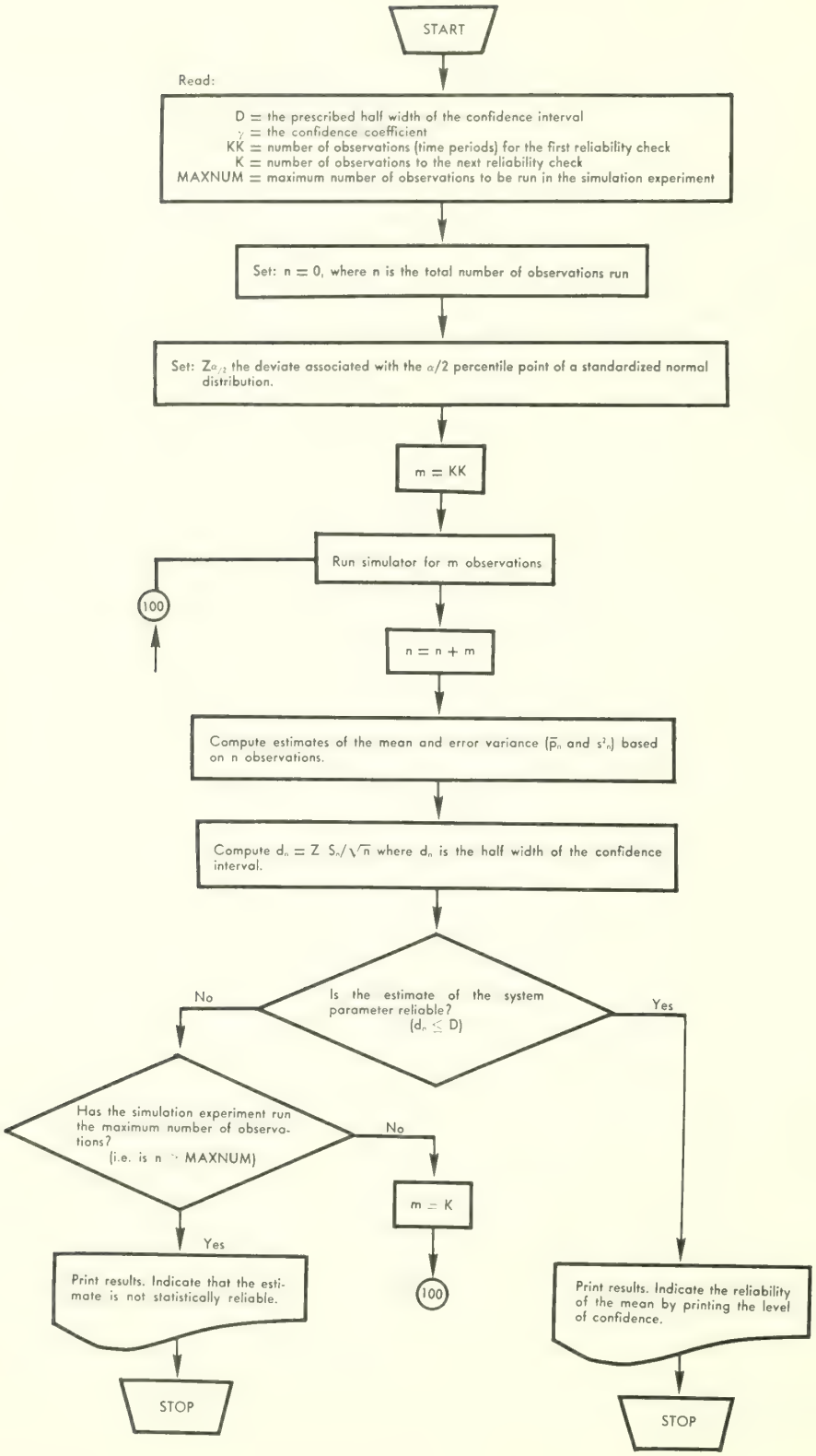
## METHODS

The sample size can be determined from interval estimates of the mean. This procedure involves setting a prescribed interval half width (D) and a probability that the population parameter falls within a distance D of the estimate and then calculating the sample size (n) needed to meet these requirements. This approach requires knowledge of the population variance ($\sigma^2$) or the assumption of a normally distributed variable. One advantage of simulation experiments is that observations can be obtained sequentially, and the results from previous observations can be retained. (One observation equals one time period in the simulator, where one time period could be 1 hour, 1 day, 1 week, 1 year, etc.) This allows one to make use of the past values in deciding whether the parameter estimates are reliable.

There are various procedures available that can be used to signal the termination of the simulation model. Reese used methods based on Chebychev's inequality, trend-corrected t tests, and sequential t tests to obtain parameter estimates after runs had reached steady state conditions. Stein's (*1945*) two-sample method, could also be used to stop the simulator run. However, in these works restrictions are imposed on the observations from the simulator. For example, normality of the variable under study has to be assumed or the simulator must run long enough to obtain a reliable estimate of $\sigma^2$.

A procedure that can be used to obtain results reliable at a prescribed probability level, and that is less restrictive than the methods previously discussed, can be obtained using a theorem by Chow and Robbins. This procedure involves estimating a confidence interval (CI) with coefficient $\gamma$ and termination of the simulator when the half width of the confidence interval ($d_n$) is less than a prescribed half width (D). If $\sigma^2$ is finite, the method will satisfy any ($\gamma$, D) reliability condition for n large enough. With $\sigma^2$ unknown and D sufficiently small, the population parameter $u_p$ will lie within the estimated interval, centered about the sample mean, with probability $\gamma$ (*Chow and Robbins 1965*).

For example, suppose we want to obtain a reliable estimate of the average daily profit $u_p$ by operating a given system for an unknown period of time. The sample size must be large enough to provide reasonable assur-


START
Read:
D = the prescribed half width of the confidence interval
γ = the confidence coefficient
KK = number of observations (time periods) for the first reliability check
K = number of observations to the next reliability check
MAXNUM = maximum number of observations to be run in the simulation experiment
Set: n = 0, where n is the total number of observations run
Set: Zα/2 the deviate associated with the α/2 percentile point of a standardized normal distribution.
m = KK
Run simulator for m observations
100
n = n + m
Compute estimates of the mean and error variance ($\bar{p}_n$ and $s^2_n$) based on n observations.
Compute $d_n = Z\ S_n/\sqrt{n}$ where $d_n$ is the half width of the confidence interval.
Is the estimate of the system parameter reliable? ($d_n \leq D$)
No
Yes
Has the simulation experiment run the maximum number of observations? (i.e. is n ≥ MAXNUM)
No
Yes
m = K
100
Print results. Indicate that the estimate is not statistically reliable.
Print results. Indicate the reliability of the mean by printing the level of confidence.
STOP
STOP

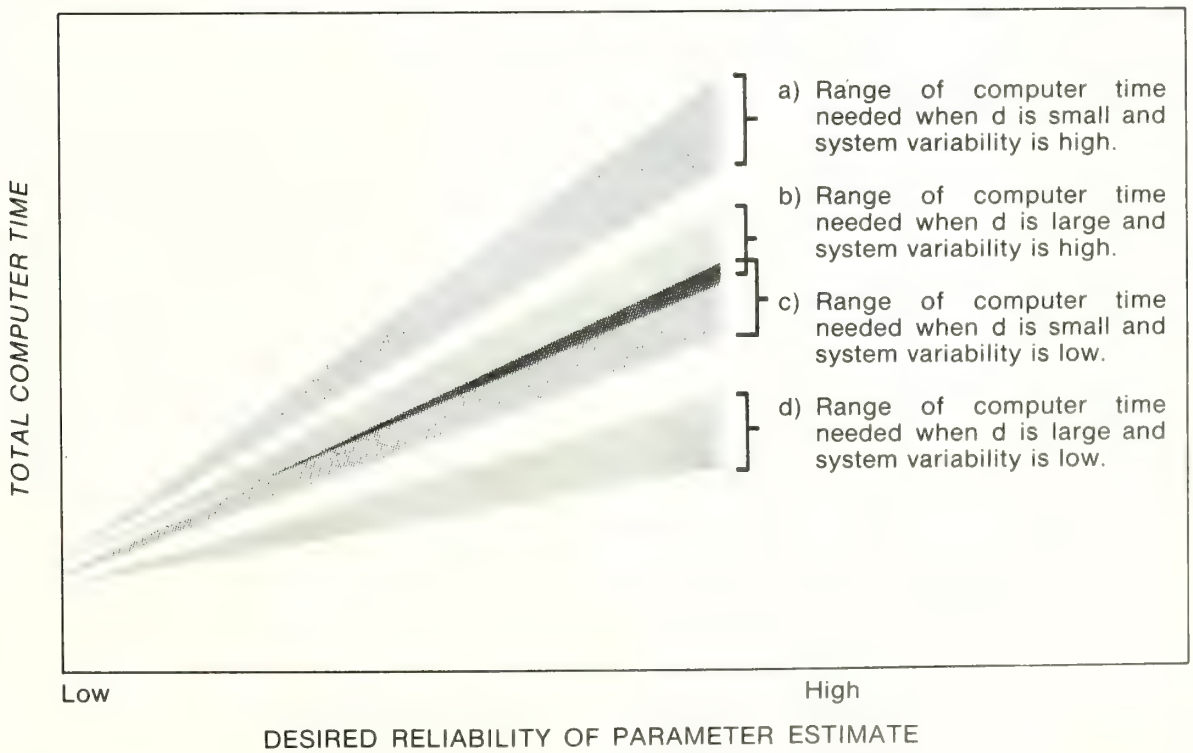
ance that $\bar{p}$, the estimated average daily profit, is close to $u_p$. Misleading results could occur if the sample size is too small. Using a sequential stopping procedure adapted from Chow and Robbin's theorem, it is necessary to make D small enough and perform the series of steps presented in figure 1.

This procedure, resulting in a fixed width confidence statement that holds asymptotically makes the sample size (n) equal to the smallest integer multiple of K greater than or equal to $Z^2S_n^2/d_n^2$ and KK. Rearranging n, from above, to appear as $d_n = ZS_n/n^{1/2}$ a reasonable procedure for ending the simulator is to stop when the simulator-estimated half width is shorter than the prescribed half width D. Although the actual confidence coefficient is no longer exactly $\gamma$ due to sequential sampling, this procedure can be used to signal an end to the simulation experiment. If the parameter estimate is assured reliability $\pm$ D at approximately the confidence coefficient $\gamma$, the results can be confidently used. If the variability is so large that reliable estimates are too costly to obtain, the simulator will stop when the maximum number of observations MAXNUM is reached.

## DISCUSSION

Examination of the flow chart (fig. 1) indicates several decisions that affect the number of observations required. A decision must be made on the prescribed half width D and on the level of confidence $\gamma$. These two values, interacting with inherent variability of the simulator, have a direct effect on the length of the simulator run. Theoretically, as shown by Emshoff and Sisson (*1970*) for any simulation experiment, the length of the computer run will be proportional to the variance (see fig. 2 a and c). This would be true whether D was small or large (see fig. 2 a and b). When the variability is high, the observations vary so much that the half width will exceed the prescribed width until n gets very large. If the model variability is small, the half width becomes less than D sooner. Figure 2, which

Figure 2. — Total computer time of simulation experiment as a function of the reliability of the estimate.


a) Range of computer time needed when d is small and system variability is high.
b) Range of computer time needed when d is large and system variability is high.
c) Range of computer time needed when d is small and system variability is low.
d) Range of computer time needed when d is large and system variability is low.
TOTAL COMPUTER TIME
Low
High
DESIRED RELIABILITY OF PARAMETER ESTIMATE

makes use of Emshoff and Sisson's work, indicates general results from any arbitrary simulation model while showing the relationship between the computer time needed for the simulation experiment, the magnitude of D, and model variability. It shows that the user of the simulation model must be very careful when choosing values for D and $\gamma$.

Even though the value of the prescribed half width D is set by the analyst, the choice is not independent of the parameters of the simulation model. D must be small relative to $\sigma^2$ and relative to the mean. A rule that is often used in calculating the sample size is to set D equal to $\pm$ 10 percent of the mean. In many cases, the analyst will have preliminary runs of the simulator available to use for estimating the mean and variance. It may also be possible to derive approximations of the mean and variance by analytical methods. It is necessary to obtain reliable results from the model, but only if the cost and time required to obtain these results do not outweigh the potential benefits of using the model.

The following is an example of the stopping rule outlined in figure 1 and the relationships shown in figure 2:

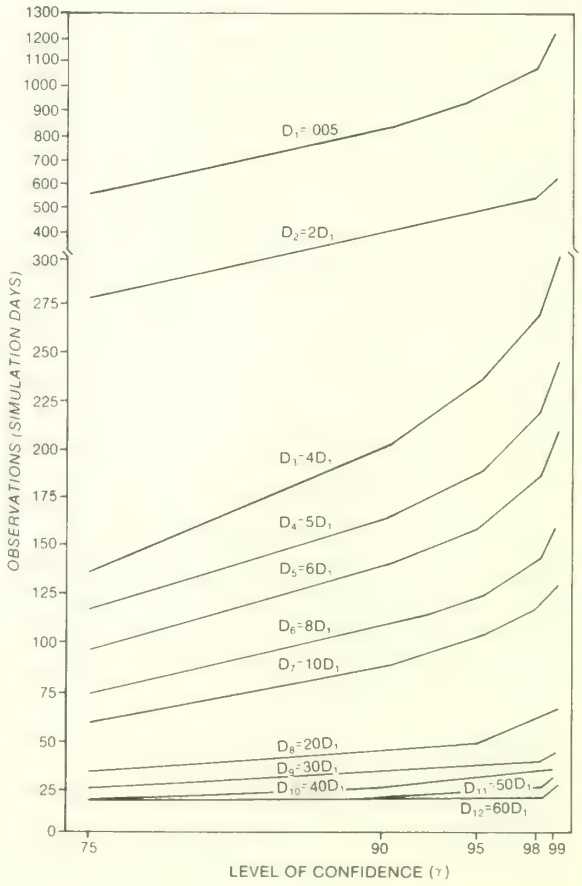
An individual has contracted to do the log hauling from a logging site 12 miles to the sawmill. The logs are purchased at $29 per thousand board feet (Mbf) from the logger and sold to the mill for $34 per Mbf. The contract requires six loads per day. The contractor is presently hauling the six loads with two trucks, but is interested in the effect on total profit if one additional truck is used. The costs (owning, fuel, maintenance, etc.) involved in running two trucks are known and provide data for estimating the costs for a third truck.

The profit for a three-truck system is determined by using a model which simulates the hauling operation through distributions of loading time, hauling time, and operator efficiency. The system is treated as a single-channel queue with the loader as the queuing point where trucks may wait for loading while another truck is loaded.

The parameter of primary interest in the simulation model is average profit per day. Since a decision whether to purchase the third truck will be based upon this parameter, it must be reliable. The mean profit should be within D units of the true value ($100 \times \gamma$) percent of the time. However, the cost of obtaining profit estimates must not be too large.

The simulation model was run using different values for D, $\gamma$, and $\sigma^2$ and graphs were plotted to show the resulting relationships. (Note: the graphs serve to point out the results from this particular example and should not be interpreted for any other use.) Figure 3 shows the length of computer runs for various $\gamma$ and D values. As the confidence coefficient increases for a fixed D value the computer time increases. Conversely, as D is decreased for a fixed $\gamma$ the time increases. The analyst may want to choose $\gamma$ and D values between the extremes of a small $\gamma$ and a

Figure 3. — Number of simulated days versus level of confidence ($\gamma$) for various levels of D.



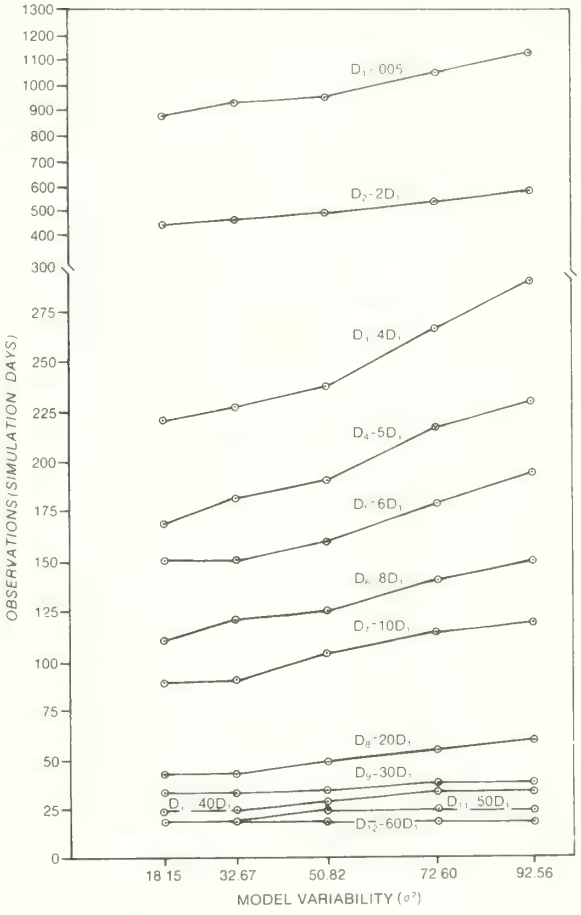
large D value resulting in a small amount of computer time, (20 observations for our example: one observation corresponds to one simulated day) and a large $\gamma$ and a small D value resulting in a great amount of computer time (1,255 observations for our example).

Figure 4 shows the length of computer runs for 5 levels of ($\sigma^2$) and 12 D values. In our example the random variables were generated from normal distributions and variability was increased by increasing the variability of two of the components. This example is just one of many ways to change the model variability. For a given D level, as $\sigma^2$ of the model increases, the time needed to obtain a reliable parameter estimate increases. When the variance is held constant and D decreased, the computer time increases. For this example, when $\sigma^2$ was small and D was large, the number of observations needed to obtain a reliable parameter estimate was small (20 simulation days); however, when $\sigma^2$ was large and D was small, the required number of observations was large (1,125 simulation days).

Thus the three factors $\gamma$, D, and $\sigma^2$ must be carefully considered when analyzing the simulation experiment results.

The analyst has the responsibility of insuring reliable results from simulation experiments. The potential savings from use of the model should not be diminished by excessive costs in obtaining the results.

Figure 4. — Number of simulated days versus model variability ($\sigma^2$) for various levels of D.

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# An Annotated List of the Cicadellidae and Fulgoridae of Elm

by Lester P. Gibson

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WARREN T. DOOLITTLE, DIRECTOR

## The Author

LESTER P. GIBSON received his bachelor of science and master's degrees from Ohio State University. He joined the Forest Service in 1957 and has served as a Biological Aide (Survey Entomologist) and Research Entomologist at Columbus and Delaware, Ohio. He is a specialist on insects of nut crops and hardwood seeds. Currently, he is engaged in research on insect vectors of tree viruses and mycoplasmas at the Northeastern Forest Experimental Station's Forest Insect and Disease Laboratory at Delaware, Ohio.

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# An Annotated List of the Cicadellidae and Fulgoridae of Elm


## Abstract

This annotated list includes 87 cicadellid and 13 fulgorid entries that were found on and probably feed on elm to some extent. Thirteen of the cicadellid species listed are known vectors of virus or mycoplasmalike diseases of plants. Also, the following 18 cicadellid genera contain known vectors of virus or mycoplasmalike diseases of plants: *Ceratagallia* Kirk., *Agallia* Curtis, *Agalliopsis* Kirk., *Chlorotettix* VanD., *Coelidia* Germar, *Colladonus* Ball, *Draeculacephala* Ball, *Empoasca* Walsh, *Endria* Oman, *Graphocephala* VanD., *Gyponana* Ball, *Idiodonus* Ball, *Keonolla* Oman, *Macrosteles* Fieb., *Osbornellus* Ball, *Paraphlepsius* Bak., *Scaphoideus* Uhl., and *Scaphytopius* Ball. One fulgorid genus, *Delphacodes*, also contains vectors of virus or mycoplasmalike diseases.

EARLY IN THE STUDY of vectors of elm phloem necrosis, it was found that few cicadellids or fulgorids that feed on elm, *Ulmus americana* L., were listed in literature. Both families contain species that are known vectors of virus and mycoplasmalike diseases. *Scaphoideus luteolus* Van Duzee was reported the vector of elm phloem necrosis (Baker 1948, 1949, 1950). However there are many more species that are potentially vectors of this disease. Hoffman (1942) lists *Empoasca bipunctata* (Oshanin), *E. fabae* (Harr.), *Erythroneura basilaris* (Say), *E. kansana* Bak., *E. maculata* (Gill), *Typhocyba ulmi* (L.), and *T. rosae* (L.), of the Cicadellidae as feeding and/or breeding on elm. He lists *Acanalonia conica* (Say), *Ormenis pruinosa* (Say), and *O. septentrionalis* (Spin.), of the Fulgoridae on elm. The following alphabetical lists of Cicadellidae and Fulgoridae are compiled from collection data, unpublished rearing data, and literature. The reared insects were collected on elm, usually as nymphs, and reared on elm seedlings by personnel of the Bureau of Entomology and Plant Quarantine, Columbus, Ohio, from 1945 to 1953.

In the citations, the following code letters have been used: CAE—collected on American elm, RAE—reared on American elm, TA—collected on trees in association with elm, and HVA—collected on herbaceous vegetation in association with or near elm. Also the plus (+) symbol has been used with the above codes to denote an abundance on one or more vegetation types.

## Cicadellidae (Leafhoppers)

*Aceratagallia sanguinolenta* (Prov.). CAE, HVA+. Recorded from alfalfa, potatoes, grasses, willow, and weeds (Medler 1942). A known vector of New York strain of potato yellow dwarf (Black 1934, Nielson 1968).

*Agallia constricta* Van D. RAE, CAE+, TA+, HVA+. Listed hosts are clovers, soybeans, and other legumes (Osborn 1928). Recorded on alfalfa and alsike clover (Stearns 1927). This species is a known vector of clover big vein and potato yellow dwarf (Nielson 1968). Also listed as a vector of wound tumor virus (Black 1944, Black & Brakke 1952).

*Agalliopsis novella* (Say). CAE, TA, HVA. Recorded on alfalfa, clover, apple, and oak (Stearns 1927); also in poplar woods, tamarack swamp, and grass areas (Medler 1942). Vector of clover big vein and clover club vein. Also listed as vector of clover leaf-club virus (Black 1944, Maramorosch 1955, Beirne 1956), wound tumor, New Jersey and New York strains of potato yellow dwarf (Black 1941, 1944).

*Alebra albostriella* (Fall). CAE, TA, HVA. Young (1957) indicates this species probably is *aurea* (Walsh) which has been collected on maple, linden, oak, chestnut, sycamore, dogwood, and elm.

*Aulacizes irrorata* (F.). CAE, TA, HVA. Recorded on oak, sassafras, and weeds in open woods (Stearns 1927).

*Balclutha* spp. CAE, TA, HVA+. Blocker (1967) states grasses and sedges usually are host plants.

*Chlorotettix* spp. CAE, TA, HVA Hosts include grasses, willow, strawberry, and salt marsh vegetation (Osborn 1915)). One species is a known vector of California aster yellows (Nielson 1968).

*Coelidia olitorius* (Say). CAE+, TA, HVA. DeLong reported sassafras as host in 1923 (Medler 1942). Host plants include apple, peach, catalpa, oak, and weeds in open woods (Stearns 1927). Note: *C. indica* Walker is a vector of sandal spike (Nielson 1968).

*Colladonus clittellarius* (Say). CAE, HVA, Beirne (1956) lists as vector of eastern X-disease of peach and cherry.

*Deltocephalus spp.* CAE, HVA. Some species recorded on lawns, wheat, oats, willow, and alsike clover.

*Dikraneura* spp. CAE, TA, HVA+.

*Draeculacephala* spp. CAE, TA, HVA+. Some species reported on alfalfa, clover, corn, timothy, and willow. Some species are vectors of Pierce's disease of grape and chlorotic streak of sugarcane (Nielson 1968).

*Empoasca* spp. CAE+, TA, HVA. Some species are vectors of bunchy top of papaya and little leaf of brinjal (Nielson 1968).

*E. bipunctata* (Oshanin). This European species taken only on elm in U. S. (Hoffman 1942). Host is Chinese elm (Beirne 1956).

*E. fabae* (Harr.). RAE. Economically destructive to apples, potatoes, legumes, vegetables, cotton, dahlia, and fruit trees. Reportedly a vector of potato yellow-dwarf.

*Endria inimica* (Say). RAE, CAE. Collected on herbaceous vegetation. Vector of striate mosaic of wheat and North American aster yellows, western strain (Nielson 1968).

*Erythroneura* spp. CAE+, TA, HVA.

*E. accola* McAtee. RAE, CAE.

*E. affinis* Fitch. RAE, CAE.

*E. alternata Johnson.* RAE, CAE. Johnson (1935) lists host as *Carpinus.*

*E. basalaris* (Say). RAE, CAE. Breeds on elm (Hoffman 1942). On plum and *Caragana* (Medler 1942).

*E. bigemina* McAtee. RAE, CAE. Johnson (1935) lists on *Ulmus*, *Aesculus*, and *Castanea.*

*E. campora* Robinson. RAE, CAE. Johnson (1935) lists as common everywhere especially on elm. Collected late May to October.

*E. comes* (Say). RAE, CAE. Hosts are *Vitis*, *Ampelopsis*, and *Cornus* (Medler 1942).

*E. contrasta.* RAE, CAE.

*E. fulvocephala* Robinson. RAE, CAE. Hosts are *Aesculus*, *Ulmus*, *Prunus*, *Vitis*, *Alnus*, *Robinia*, *Carpinus*, *Salix*, *Cercis*, and *Juglans* (Johnson 1935).

*E. harpax* Beamer. RAE, CAE. *Aesculus* is host (Johnson 1935).

*E. kansana* Baker. RAE, CAE. Taken only on elm (Hoffman 1942). Collected on Rumex (Medler 1942).

*E. lawsoni* Robinson. RAE, CAE. Common on sycamore in Ohio (Johnson 1935).

*E. maculata* (Gill.). RAE, CAE+. On sycamore and alfalfa (Stearns 1927)). On *Aesculus* (Johnson 1935). Host plant is sumac (Beirne 1956).

*E. noeva* (Gill.). CAE. Taken on *Carpinus*, *Quercus*, *Malus*, *Gleditsia*, *Aesculus*, *Juglans*, and *Acer pictum.* All stages found on last two hosts (Johnson 1935).

*E. obliqua* (Say). RAE, CAE. Taken on *Carpinus*, *Aesculus*, and *Ulmus* (Johnson 1935).

*E. osborni* (DeL.). RAE, CAE. On *Carpinus* (Johnson 1935).

*E. rubens* (Beamer). CAE.

*Eutettix* spp. Collected on American elm and nearby trees.

*Graminella fitchii* (Van D.). Rarely collected on American elm. Collected on herbaceous vegetation.

*Graphocelphala coccinea* (Forst). RAE, CAE+, TA, HVA. Hosts are apple, peach, oak, alsike clover, timothy, and weeds (Stearns 1927). Common on shrubby vegetation (Osborn 1928).

*G. versuta* (Say). CAE, TA, HVA. Hosts include alsike, clover, ragweed and *Pinus virginiana* Mill. (Stearns 1927). Vector of phony peach disease (Turner 1949, Nielson 1968).

*Gypona* sp. RAE, CAE, TA, HVA.

*Gyponana octolineata* complex. CAE. Hosts include grasses, low herbage, bushes, and trees (Osborn 1915). One species of this genus is a vector of aster yellows and one is a vector of eastern X-disease of peach (Nielson 1968).

*Idiodonus kennecotti* (Uhl.). CAE, TA, HVA. One species of *Idiodonus* is a vector of aster yellows (Nielson 1968).

*Keonolla dolobrata* (Ball) = *Neokolla gothica* (Signoret). CAE, HVA. Vector of Pierce's disease of grape (Nielson 1968, Ishihara 1969).

*Kolla bifida* (Say). CAE, TA. On alfalfa, orchard grass, and oak (Stearns 1927). Many collected on herbaceous vegetation.

*Latalus sayi* (Fitch). Scarce on American elm. Collected on herbaceous vegetation. Abundant on bluegrass in Indiana (Brown 1939).

*Lonenus intricatus* (Uhler). RAE.

*Macrosteles divisa* (Uhler). CAE, HVA. Medler (1942) recorded this species as damaging oats and as a vector of aster yellows virus. Beirne (1956) says *M. fascifrons* (Stal.) is the correct name for the leafhopper which is a vector of aster yellows, lettuce yellows, white-heart, rabbit ear, and Rio Grande disease of lettuce, purple top and net necrosis of potato, flax crinkle, oat blue dwarf, and other yellows diseases. Six species of *Macrosteles* are known vectors of virus and viruslike diseases.

*Menosoma cincta* (O. & B.). Scarce on American elm and nearby trees.

*Neokolla seminuda* (Say). CAE, TA, HVA.

*Osbornellus auronitens* (Prov.). RAE, CAE. Beirne (1956) states ferns are probably hosts. Rarely collected on trees near elm and from grass and weeds. Note: *O. borealis* is the vector of a yellow leafroll strain of western X-disease of peach (Nielson 1968).

*O. clarus* Beamer. Collected on *Ulmus alata* Michx.

*Paraphlepsius irroratus* (Say). RAE, CAE, TA, HVA, Serious pest of grain crops and other plants (Brown 1939). On alfalfa, alsike clover, oak, apple, and peach (Stearns 1927). Population heavy on American elm in 1946. Vector of clover phyllody virus (Chiykowski 1965).

*Phlepsius* sp. CAE, TA, HVA+.

*P. leucopthalmus*. RAE.

*Ponana* sp. CAE, TA, HVA.

*Scaphoideus* spp. CAE+.

*S. atlantus* Ball. RAE, CAE+, TA. Also collected on winged elm, ragweed, teasel, mustard, *Dipsacus* sp., & Early Marvel pea.

*S. auctus* DeL. & M. CAE.

*S. cinerosus* Osb. CAE.

*S. crassus* DeL. & M. RAE, CAE, TA. Also collected on grass and weeds.

*S.* near *dilatus* DeL. & M. CAE.

*S. diutius* DeL. & M. CAE.

*S. flexus* DeL. & M. CAE, TA.

*S. immistus* (Say). CAE+, TA. Osborn (1915) lists willow as host. Collected on apple, oak, Japanese maple, elm, and weeds (Stearns 1927). Host possibly *Salix* spp. (Beirne

1956). Commonly collected on winged elm and on grass and weeds.

*S. littoralis* Ball. CAE+, TA, HVA. This species, the vector of a yellows disease, "Flavescence doree" of grape in France, is also found in Italy on grape (Vidano 1964).

*S. luteolus* Van D. RAE, CAE+. Osborn (1928) reported this species was apparently rare. Collected on American elm by the thousands from 1940 through 1952. Rarely collected on poison ivy and Virginia creeper. Collected on winged elm. Reported as the vector of elm phloem necrosis disease (Baker, 1948, 1949, 1950).

*S. major* Osb. Host probably willow (Beirne 1956). One collected on American elm.

*S. melanotus* Osb. CAE.

*S.* near *merus* DeL. & B. CAE, TA.

*S. minor* Osb. CAE, TA, HVA.

*S. nigrellus* DeL. & M. RAE, CAE.

*S. nigricans* Osb. RAE, CAE+. Collected on grass and weeds and on *Washingtonia claytoni* Clarke *(Osmorhiza claytoni* [Michx] Clarke).

*S. obtusus* Osb. CAE.

*S. pullus* DeL. & M. CAE, TA, HVA.

*S. radix* DeL. & M. CAE, TA.

*S. scelestus* DeL. & M. RAE, CAE, TA, HVA. Collected on winged elm.

*S. sensibilis* Ball. RAE, CAE. Common on *Osmorhiza claytoni.*

*S. tergatus* DeL. CAE.

*S. torgus* DeL. & B. CAE, HVA.

*Scaphytopius* sp. CAE, TA, HVA.

*S. acutus* Say. CAE, TA, HVA. Vector of western X-disease of peach and cherry (Beirne 1956). Vector of alfalfa witches' broom, eastern X-disease of peach, little cherry, clover phyllody, and western aster yellows (Nielson 1968). Vector of eastern X-disease of peach and lucerne witches' broom (Ishihara 1969). Chiykowski (1962) studied the role of this species as a vector of clover phyllody in Canada.

*S. frontalis* (Van D.). CAE, TA, HVA. Ball listed blackberry as host (Medler 1942).

*Stirellus obtusus* (Van D.). CAE, TA, HVA.

*Typhlocyba* sp. RAE, CAE, TA, HVA.

*T. rosae* (L.) (=Edwardsiana). Nymphs and adults feed on apple, rose, and elm (Hoffman 1942). Hosts are apple, rose, plum, and *Rubus* sp. (Beirne 1956).

*T. ulmi* (L.) (=Ribautiana). Responsible for spotting of elm leaves (Hoffman 1942). Probably introduced from Europe, elm is host (Beirne 1956).

*Xestocephalus brunneus* Van D. CAE, TA, HVA. Common on willow and black locust in Indiana (Brown 1939).

*Xestocephalus pulicarius* Van D. CAE, TA, HVA. Osborn stated *Carex vulpinoides* is normal host (Medler 1942).

## Fulgoridae (Planthoppers)

*Acanalonia bivittata* (Say). CAE, TA. Abundant on herbaceous vegetation.

*A. conica* (Say). RAE, CAE, TA, HVA.

*Amalopta* sp. CAE, HVA.

*Apache degeeri* (Kby). CAE, TA.

*Cedusa* sp. CAE, TA. Collected on herbaceous vegetation.

*Cixius* sp. CAE, TA. Collected on herbaceous vegetation.

*Delphacodes* sp. CAE, TA. Most collected on herbaceous vegetation. Species of this genus are vectors of rice stripe (Maramorosch 1963), oat striate-dwarf, wheat striate mosaic (Prusa, et al 1959), maize rough dwarf (Maramorosch 1963), oat dwarf tillering, and black-streaked rice dwarf (Shinkai 1962).

*Oliarus* sp. CAE, TA.

*O. vicarius* Walker. CAE, TA.

*Ormenis pruinosa* (Say). RAE, CAE+, TA, HVA. Lives on elm (Hoffman 1942).

*O. septentrionalis* (Spin.). CAE+, TA, HVA. Hoffman (1942) lists elm as host.

*O. venusta* Melich. CAE, TA. Collected on herbaceous vegetation.

*Thionia* sp. CAE, TA. Collected on herbaceous vegetation.

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# Sawing SHOLD LOGS: Three Methods

by Ronald E. Coleman
and Hugh W. Reynolds

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

# Sawing SHOLO LOGS: Three Methods


## ABSTRACT

Three different methods of sawing the SHOLO log were compared on a board-foot yield basis. Using sawmill simulation, all three methods of sawing were performed on the same sample of logs, eliminating differences due to sampling. A statistical test was made to determine whether or not there were any real differences between the board-foot yields. Two of the sawing methods provided about the same board-foot yields; one provided about 40 percent less.

IN THE APPALACHIAN AREA, there are large quantities of low-grade hardwood logs that cannot be profitably converted to products by conventional sawing methods. To solve this problem for factory-grade 3 and local-use class logs, the SHOLO (from SHOrt LOg) concept was developed *(Reynolds and Gatchell 1970)*. The SHOLO concept means that each processing step after the tree is felled is aimed at producing specific products or product parts. Long, low-grade logs are bucked into SHOLO logs, which contain the desired end product and an allowance for end trim. Conventional lumber is not produced. If the SHOLO procedure is used, gross defects are eliminated at the bucking station; and the effect of allowable defects can be minimized by proper positioning of the SHOLO log relative to the saw.

It is easy to buck the SHOLO log from long logs. But once a SHOLO log is bucked, there is a question as to the best way to saw it into boards. We used computer simulation *(Reynolds and Gatchell 1969)* to compare three different methods for converting SHOLO logs into acceptable parts *(Reynolds and Gatchell 1970)* for the standard 48- by 40-inch warehouse pallet. Other products, such as furniture or flooring cuttings, could have been made. We found that the best way was to live-saw SHOLO logs into boards and then selectively rip these boards into pallet parts. We based our conclusion on yield of acceptable pallet parts.

## Comparing Sawing Methods by Computer Simulation

Computer simulation provides a precise way of comparing sawing methods. All methods are compared on the same sample of logs, thus eliminating any sampling error. We chose a representative sample *(Goho and Wysor 1970)* of 150 factory-grade 3 red oak logs having a diameter range of 8 to 18 inches. These logs were bucked into SHOLO logs for pallet parts, and 150 of the SHOLO logs were randomly selected for study. All 150 qualified for the length class (44 inches) of deckboards and 100 of the selected SHOLO logs qualified for the length class (52 inches) of stringers.

Each of the 150 SHOLO logs was actually live-sawed into 1-inch thick boards. The location and size of all defects in each board were determined, and the SHOLO logs were then reconstructed within the computer. Then, by computer simulation, the SHOLO logs were sawed into boards, using three preselected sawing methods. The boards were then converted into pallet parts. Comparisons of sawing methods were based on yield of acceptable pallet parts.

The standard warehouse pallet (48 by 40 inches) contains deckboards that are 1 inch thick and either 4 or 6 inches wide and 40 inches long and stringers that are 2 inches thick, 4 inches wide, and 48 inches long. For computer simulation, the minimum face width in live-sawing for the first cut was 4 inches. The thickness of boards was either 1 or 2 inches plus ⅛-inch saw kerf. Where the sawing method called for production of cants, one face of the cant was either 4 or 6 inches wide, and the adjacent face width was in multiples of product thickness (1 or 2 inches) plus resaw kerf. Cant dimensions and locations were adjusted to optimize part production.

## Sawing Methods

Three sawing methods were combined with the SHOLO concept for the study: (1) selective, (2) gang, and (3) combination. The selective method (fig. 1) is based on live-sawing SHOLO logs into boards and selectively ripping and end-trimming these boards into parts. The SHOLO log is placed on the carriage of a circular saw or band saw with the poorest face of the log facing the saw blade to minimize the effects of allowable defects. The boards are positioned manually on the ripsaw to obtain the desired quality of parts of prespecified widths. The final step is to end-trim the parts to specific product

Figure 1.—Selective-method flow chart.

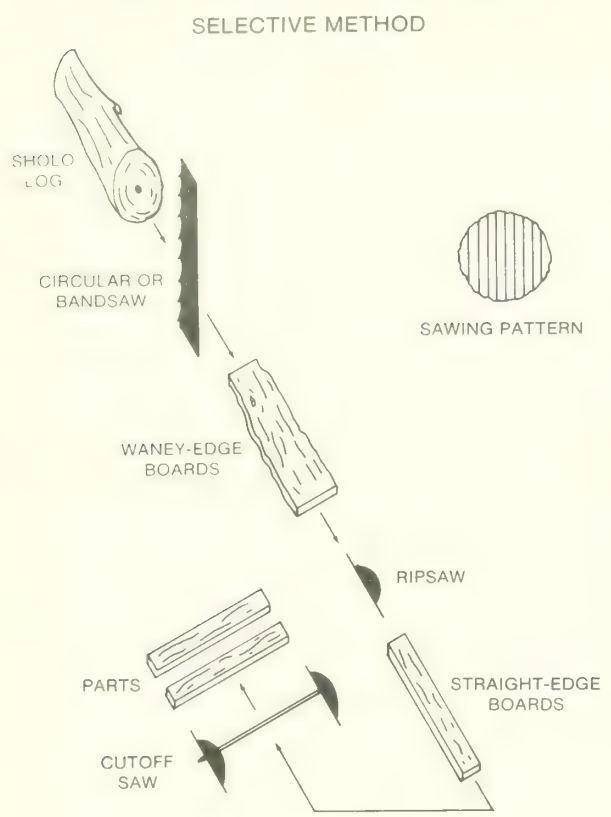
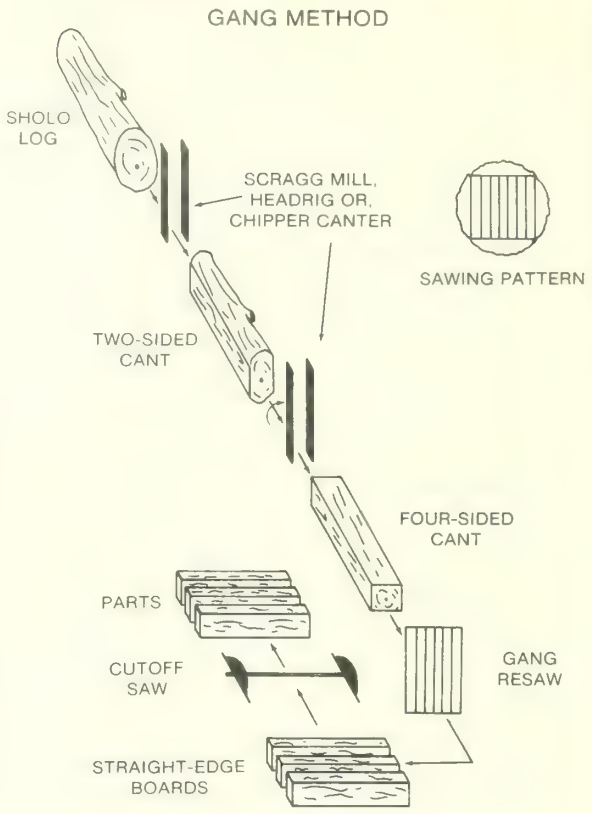



Figure 2.—Gang-method flow chart.




lengths. The quality of the part can sometimes be increased at the end-trim station by maneuvering the board to eliminate end defects.

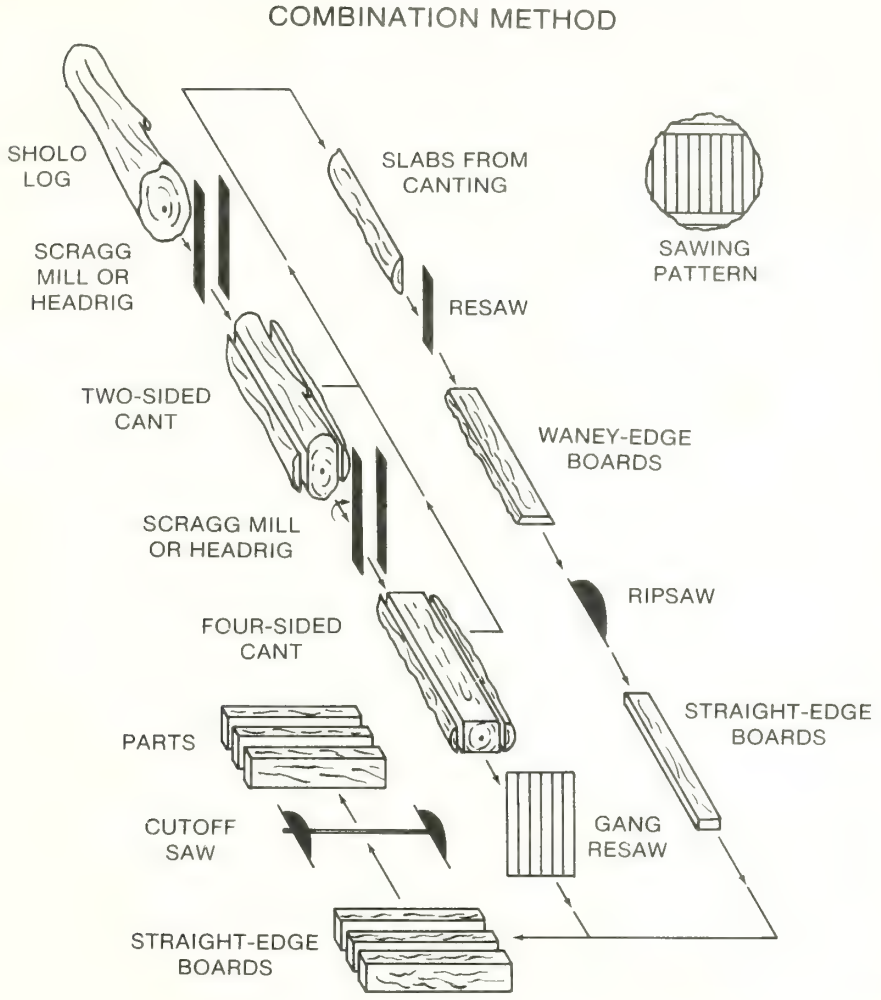
The gang method (fig. 2) produces a cant (or cants if the log is large enough) of specific dimensions that is resawed into boards. When end-trimmed, these boards match the preselected product dimensions. The gang method gives a high production rate, but about 30 percent of the volume of the SHOLO log is lost because the slabs are not used for parts production.

The combination method (fig. 3) combines the operations of the selective and gang methods. A cant is produced by slabbing the SHOLO log to the dimensions required by the gang method. Subsequent processing of the cant is the same as that for the gang method. If each slab is large enough to produce a board with a minimum 4-inch face, it is resawed into pallet cuttings, which are then selectively ripped and end-trimmed.

## The Study

Two computer simulation programs were used to determine the yield of acceptable product parts. Program DEFECT, which contained the SHOLO log-defect data library, was used to simulate sawing the SHOLO logs into boards according to the sawing pattern of the particular sawing method. When cants were produced, a different sawing pattern was used for each 1-inch increment of log diameter to take maximum advantage of larger log size. The output of program DEFECT was boards with all defects portrayed. This output was used as input to program YIELD,

Figure 3.—Combination-method flow chart.




which simulates the ripping and end-trimming operations.

Program YIELD searched each board for the widest cutting first. Because all deckboards were either 4 or 6 inches wide, program YIELD would always seek out a 6-inch wide cutting from all boards greater than 6 inches in width. If no cutting of sufficient quality could be found, the program searched for satisfactory 4-inch wide cuttings. This operation was not necessary in the production of stringers because they were all 4 inches wide.

The output data from program YIELD were converted to board-foot measure, and a yield comparison was made among the sawing methods.

## Comparing Yields

In the production of 1-inch (table 1) and 2-inch thick parts (table 2), the selective method produced a slightly greater board-foot yield than the combination method. The selective method also produced the highest percentage of wide parts (table 3). Of all three methods, the gang method produced the least yield.

Tests were made by means of covariance analysis (data available upon request) to determine whether or not there was a real difference of board-foot yields among the sawing methods. The results of these tests showed that there was no real difference between the board-foot yields of the combination and the

Table 1.—*Board-foot yields of 1-inch thick parts*
(by computer simulation)

| Number of SHOLO logs | Diameter (inches) | Board-foot yields | | |
|---|---|---|---|---|
| | | Gang | Combination | Selective |
| 7 | 8 | 15.68 | 29.67 | 26.85 |
| 18 | 9 | 58.24 | 93.33 | 94.04 |
| 12 | 10 | 40.71 | 63.67 | 65.88 |
| 13 | 11 | 46.47 | 91.23 | 83.61 |
| 16 | 12 | 83.63 | 124.18 | 125.38 |
| 16 | 13 | 74.45 | 162.09 | 192.02 |
| 17 | 14 | 157.54 | 237.68 | 256.50 |
| 19 | 15 | 179.94 | 280.42 | 309.55 |
| 6 | 16 | 75.45 | 130.11 | 162.80 |
| 13 | 17 | 211.76 | 327.23 | 360.08 |
| 13 | 18 | 249.37 | 369.85 | 401.30 |
| 150 | — | 1,193.24 | 1,909.46 | 2,078.01 |

Table 2.—*Board-foot yields of 2-inch thick parts*
(by computer simulation)

| Number of SHOLO logs | Diameter (inches) | Board-foot yields | | |
|---|---|---|---|---|
| | | Gang | Combination | Selective |
| 5 | 8 | 10.68 | 10.68 | 13.35 |
| 11 | 9 | 32.04 | 66.75 | 64.08 |
| 9 | 10 | 48.06 | 58.74 | 66.75 |
| 9 | 11 | 37.38 | 74.76 | 61.41 |
| 9 | 12 | 37.38 | 69.42 | 72.09 |
| 13 | 13 | 64.08 | 120.13 | 114.81 |
| 10 | 14 | 109.47 | 165.54 | 197.58 |
| 13 | 15 | 98.79 | 200.25 | 213.60 |
| 4 | 16 | 53.40 | 90.78 | 109.47 |
| 8 | 17 | 138.84 | 226.95 | 229.62 |
| 9 | 18 | 216.27 | 315.06 | 331.08 |
| 100 | — | 846.39 | 1,399.06 | 1,473.84 |

Table 3.—*Parts yields of 1-inch thick parts*
(by computer simulation)

| Number of SHOLO logs | Diameter (inches) | Number of parts | | | | | |
|---|---|---|---|---|---|---|---|
| | | Gang | | Combination | | Selective | |
| | | 1x4 | 1x6 | 1x4 | 1x6 | 1x4 | 1x6 |
| 7 | 8 | 14 | 0 | 25 | 1 | 13 | 7 |
| 18 | 9 | 52 | 0 | 55 | 19 | 35 | 33 |
| 12 | 10 | 11 | 17 | 25 | 21 | 29 | 20 |
| 13 | 11 | 40 | 1 | 74 | 5 | 40 | 24 |
| 16 | 12 | 73 | 0 | 90 | 14 | 60 | 33 |
| 16 | 13 | 62 | 4 | 92 | 35 | 79 | 62 |
| 17 | 14 | 84 | 38 | 98 | 74 | 65 | 110 |
| 19 | 15 | 108 | 35 | 149 | 66 | 90 | 125 |
| 6 | 16 | 45 | 15 | 61 | 37 | 38 | 72 |
| 13 | 17 | 34 | 104 | 79 | 143 | 71 | 168 |
| 13 | 18 | 81 | 95 | 117 | 143 | 75 | 190 |
| 150 | — | 604 | 309 | 865 | 558 | 595 | 844 |

selective methods. However, there was a difference between the board-foot yields of the gang method and the other two methods. Comparison of regression lines showed that the board-foot yield of parts obtained from the gang method would be about 60 percent of the board-foot yield from the selective or combination method.

## Conclusions

To obtain the greatest board-foot volume, a SHOLO log should be sawed by either the selective or combination method. If, however, a greater ratio of wide to narrow cuttings is desired, the SHOLO log should be sawed by the selective method because more selection is available at the ripping station. The combination method eliminates any selectivity within the cant it produces. Although the degree of quality of the cuttings is beyond the scope of this paper, we believe that the selective method will produce the highest quality cuttings.

The gang method gives a high production rate, but the yield will be about 40 percent less than from the selective or combination methods. This large loss is due primarily to utilizing the slabs for a secondary product rather than parts. The use of the gang method is not advised unless a very high price is available for a chipped or pulverized secondary product. In most areas, the value per pound of parts is many times the value per pound of chips or other secondary products.

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# A System for Gathering Small Mammal Mortality Data

*by Robert D. Neely*
*and Robert W. Campbell*

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NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

*The Authors*

ROBERT D. NEELY received his bachelor of science degree in electrical engineering from Grove City College in 1969. He joined the USDA Forest Service, Northeastern Forest Experiment Station, in Hamden, Connecticut, in 1969.

ROBERT W. CAMPBELL received his bachelor's degree in forestry from the State University of New York College of Forestry at Syracuse and his master's and Ph.D. degrees in forestry from the University of Michigan. He joined the Northeastern Forest Experiment Station's Forest Insect & Disease Laboratory in Hamden, Connecticut, as a research entomologist in 1961. He is now principal ecologist, located at Syracuse University.

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# A System for Gathering Small Mammal Mortality Data

*Abstract*

As an aid to studying vertebrate predators of the gypsy moth, a radio telemetry system was designed to detect the death of small mammals and facilitate recovery of the remains. An intraperitoneally implanted radio transmitter is triggered by the drop in body temperature when the animal dies. The device was tested in white-footed mice.

PREDATION by the white-footed mouse, *Peromyscus leucopus* (Raf.), is important in the population dynamics of the gypsy moth, *Porthetria dispar* (L.).

Observations on many forest pests not only suggest that predation processes are a principal deterrent to outbreaks of forest insects, but also support the notion that much of this predation is by birds and mammals *(Knight 1958, Buckner 1967, Hamilton and Cook 1940, Morris et al. 1958, Holling 1959)*.

The white-footed mouse preys on the larger larvae and pupae of the gypsy moth; and among sparse populations of the insect, this predation determines whether these populations will remain innocuous or will increase to dangerously high levels *(Campbell 1967, Bess et al 1947)*.

This latter fact raises the possibility that we could achieve more rational management of the gypsy moth population system through measures designed to promote and maintain more dense populations of this predator. Thus we have become interested in what might be termed "Peromyscus management." And we think that any rational scheme for managing these mammals should be based, in part, on a thorough understanding of the sources of *their* mortality.

But unfortunately, very little is known about the role of naturally occurring mortality in the population dynamics of *Peromyscus* spp. In fact, Terman *(1968)* in a recent monograph on *Peromyscus*, stated: "The data presently available on [*Peromyscus*] populations are suggestive of sensitive controlling mechanisms which are by no means understood" and that "the demonstration of factors characteristic of or associated with population control in nature is extremely difficult and almost non-existent in the literature of *Peromyscus*."

We think a new approach, which incor-

porates the following premises, might shed new light on this problem:

1. A transmitter could be developed, which would be small enough for implanting intraperitoneally, in a white-footed mouse. This transmitter would remain effective for at least 2 years and would switch on when the host died.
2. The transmitter unit would not interfere with the life processes of the host animal.
3. A receiver grid could be developed that would assure reception of transmitter signals.
4. Careful autopsy of the animal's remains would reveal cause(s) of death.

Our progress to date in meeting the above objectives is reported here.

## Background

Although the success of a mortality monitoring system for small mammals is, to a large extent, an inverse function of the size of the implanted radio transmitter, some guidelines are needed to establish a working frame of maximum acceptable size and weight. Transmitter size, in the case of *Peromyscus*, was conceptually constrained by the size of the mature bot fly larva, a generally non-fatal parasite of this genus. Pending results of intensive biological testing, a weight limit for the transmitter was set at about 1 g, which is about 5 percent of the average weight of an adult mouse.

The transmitter must have a shelf life of 2 years, a reasonable transmitting range, and some way of "sensing" when its host is dead. Ideally, a continuously running transmitter would not only allow us to track the living animal, but would also allow us to locate the remains after the animal dies.

Unfortunately, the amount of energy available from present energizers, within the size restriction, cannot approach that necessary to power an active oscillator for 2 years. Thus the oscillator must remain passive while the mouse is alive, and switch on after death to meet the 2-year availability requirement.

Most of the possible ways to build a "death switch" were rejected because of surgical complexity, size restriction, and electrical limitations. Mathematical investigation of several bimetallic thermoswitch configurations demonstrated feasibility of this method and led to the final shape design. Empirical trials were used to determine the minimum dimensions of the switch for reliable control of the oscillator.

Several types of blocking oscillators were considered; the chosen circuit was selected on the basis of simplicity, peak power from a 1.3-volt source, and relatively narrow band width. Physical layout of the circuit, component values, and coil dimensions were optimized for small size and stability.

Nonmetallic housing was needed to provide operating space for the thermoswitch and to protect the circuitry against both corrosive body fluids and direct bites by predators. The best housing shape was visualized as one that would allow maximum payload insertion through a small incision while minimizing irritation to internal organs. This shape was found in the form of a standard medication capsule. Both glass and high-purity alumina ceramic were investigated as housing materials, but the problems involved in construction and sealing encouraged the use of epoxy for potting the transmitter, followed by a layer of paraffin to seal out body fluids *(Mackay 1970)*, and a final coating of silicone rubber to facilitate handling and surgical implantation.

## Results

The transmitter consists of an energizer, a thermoswitch, and an oscillator (fig. 1). These are secured together with epoxy, connected electrically, and encapsulated. The completed unit is sterilized with a standard solution of zephiran chloride and surgically placed in the peritoneal cavity.

A mercuric oxide energizer, type 212, provides power for the oscillator. Connections to the energizer are made by capacitive-discharge wire welds that are strain-relieved with epoxy cement.

The thermoswitch (fig. 2) is based on .127 mm thick bimetal stock (Chace #6650)[1]

[1]Mention of a product is for information only and should not be considered a recommendation or endorsement by the U. S. Department of Agriculture or Forest Service.

Figure 1. — Electronics assembly: transmitter parts mounted with epoxy on small wafer.

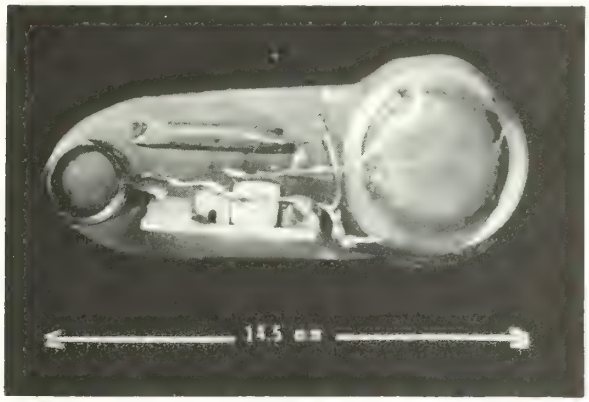
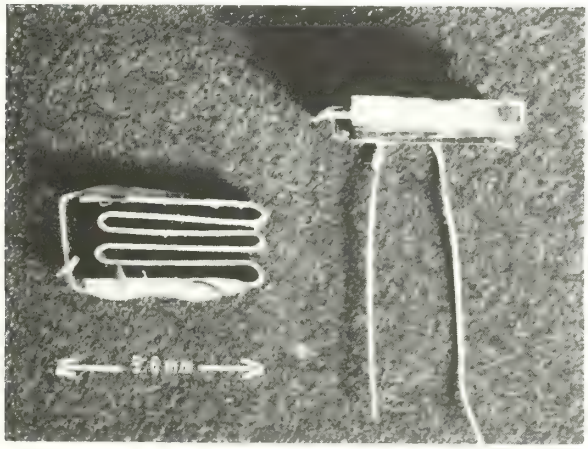



Figure 2. — Thermoswitch: side and top views.



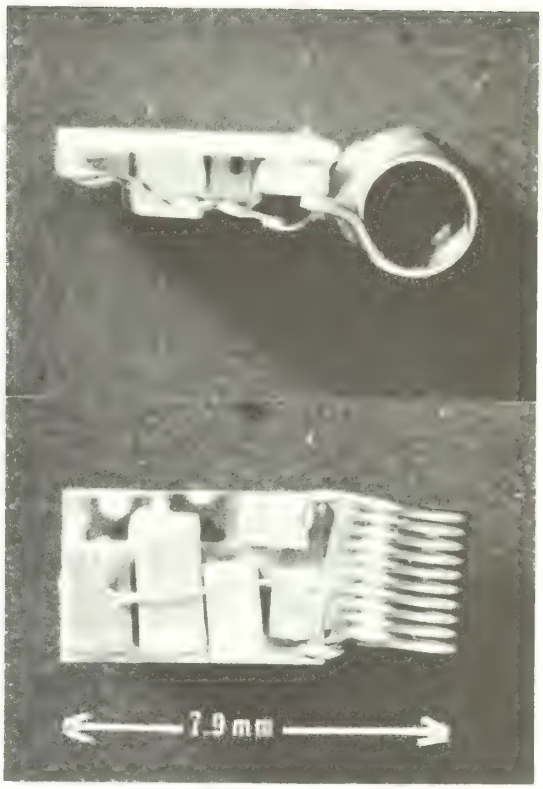
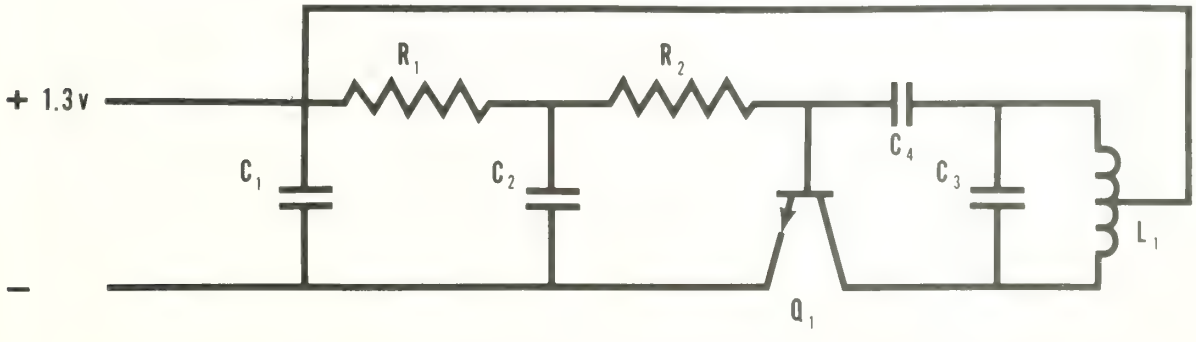



Figure 3. — Oscillator: side and top views.

Figure 4. — Schematic diagram: oscillator. $C_1$ — .01 uf, K 1800 ceramic, chip. $C_2$ — .03 uf, K 1800 ceramic, chip. $C_3$ — 100 pf, NPO ceramic, chip. $C_4$ — 100 pf, NPO ceramic, chip. $R_1$ — 91K ohm, thick film. $R_2$ — 7.5k ohm, thick film. $Q_1$ — 2N2369, chip. $L_1$ — Air core, 2.54 mm. O. D., 10 turns #30 enameled wire, close-wound, tapped at 4 turns from collector.



sheared to a width of .66 mm and folded accordion-like into six sections, 5.08 mm in length. Contacts are fastened to the bimetal body by spot welds and epoxy cement. The epoxy provides strain relief for the weld joints associated with one contact and secures the second contact while insulating it from the bimetallic body. A decrease in temperature closes the contacts; contact closure is tentatively set at 26°C. (Normal body temperature of *Peromyscus* is about 34°C). Platinum wire is used for the switch contacts to increase the reliability of electrical contact.

The blocking oscillator (fig. 3 and 4) produces bursts of radio frequency energy at 46.8 MHZ with a repetition rate of about 600 pulses per sec. Maximum transmitting range is about 45 m, with no external antenna connected to the oscillator, and with a quarter wave (whip) antenna connected to the receiver. (Low-band VHF monitor, with an AM detector and input sensitivity of .7 uv for 10:1 signal to noise ratio.)

The transmitter components are protected by carefully encapsulating the electronics assembly. A heat lamp is used during this process to create a microclimate of about 30°C at 40 percent or less relative humidity to promote optimum curing of the epoxy and to prevent closure of the switch contacts and subsequent draining of the energizers. If a fast-setting epoxy (Armstrong A-36) is used, walls can be formed around the switch, to allow sufficient clearance for unhindered motion of the mechanically active switch contact.

After the switch is completely enclosed, the oscillator and energizer are potted with the epoxy and the unit is washed in acetone for 5 seconds, then filed to remove any sharp protrusions. The epoxy capsule is covered with paraffin by dipping both ends separately into a paraffin bath, allowing sufficient time between applications for the first to cure to handling consistency. An overlap between coatings assures adequate sealing. Silicone rubber (Dow-Corning 3110 RTV) is then applied in two steps as above, but a small spatula is used to apply the material. Weights of the transmitter and its components are listed in table 1.

Table 1. — *Weight of transmitter parts*

| Part | Weight (g) |
|---|---|
| Oscillator | 0.09 |
| Thermoswitch | .03 |
| Energizer | .32 |
| Epoxy | .33 |
| Paraffin | .06 |
| Silicone rubber | .13 |
| Transmitter | .96 |

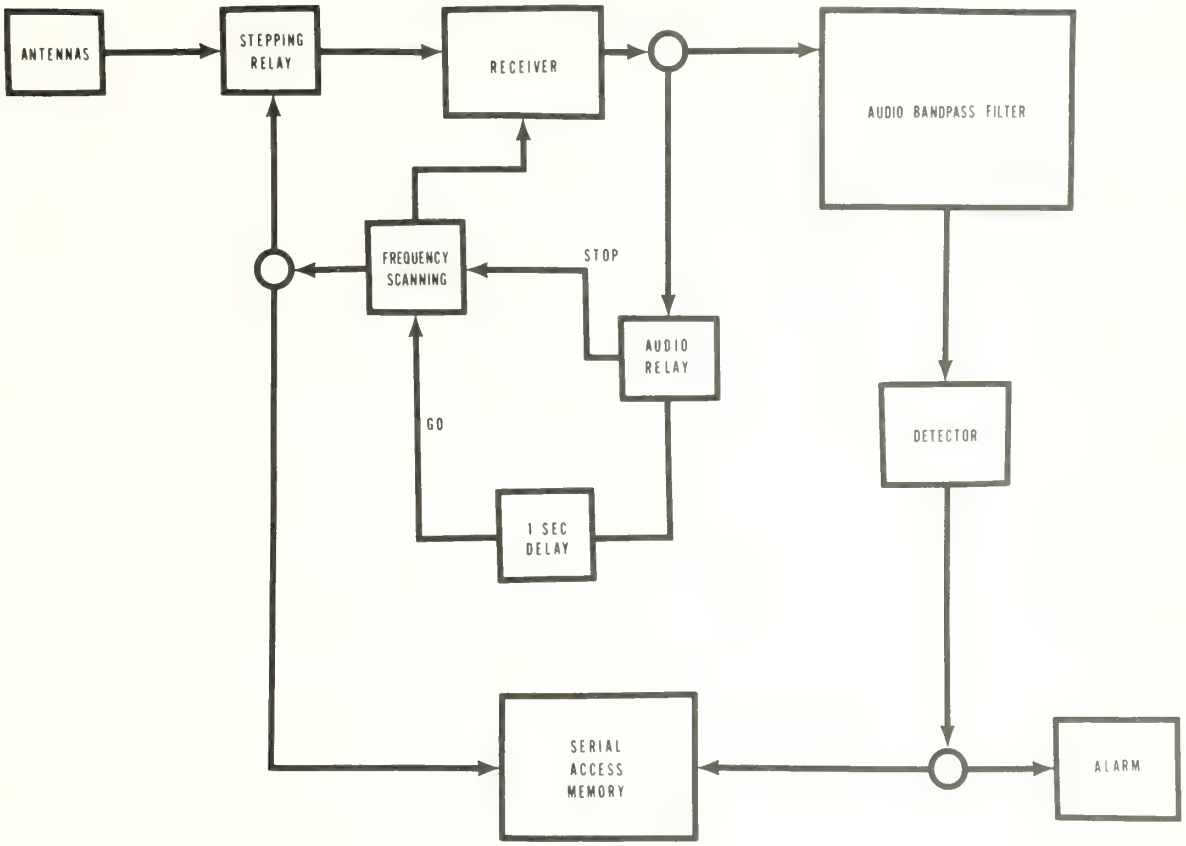
Values indicated are nominal. Total weight may vary ± .04 g.

Signals are received from the transmitter by a grid system of antennas arranged close enough together (about 15 m) to assure reception of signals from implanted transmitters anywhere within the grid boundary. The antennas are connected sequentially to a receiver, which is modified to scan a frequency spectrum around the operating point to compensate for carrier frequency differences between the transmitters. The frequency scanning mechanism also controls the antenna stepping relay so that, after each frequency scan, the next antenna in the interrogation sequence is connected to the receiver input.

If a signal is present at an antenna when it is sequenced onto the receiver input, an audio relay stops the frequency scanning as the receiver is tuned onto the signal. A delay circuit allows about 1 second for analysis of the signal before the scanning process is resumed. An active audio bandpass filter followed by a detector determines whether the signal is from an implanted transmitter or whether it is extraneous. The input of the bandpass filter includes a limiter circuit to maintain a constant-amplitude input to the filter. In the detector, rectification and integration of the filter output converts the frequency-dependent AC amplitude to DC amplitude, which is detected by a Schmitt trigger. If a valid signal is detected by the receiver, the Schmitt trigger switches to the "on" or "1" state.

This logic level of "1" is stored in a serial access memory at the address dictated by the antenna interrogation sequence. The "1" state also activates an alarm, which may be transferred via telephone lines, to summon an

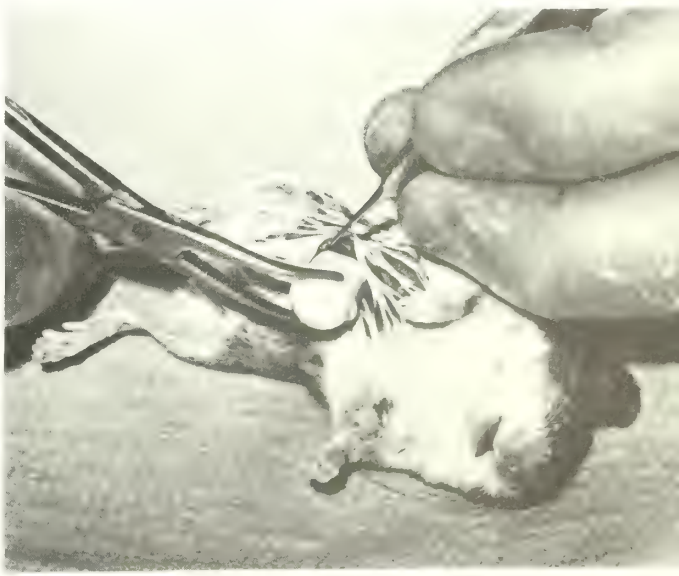
Figure 5. — Receiving system: block diagram.




attendant to the area. (Block diagram of receiving system appears in figure 5.) Using the recorded antenna identification and a portable receiver, the attendant pinpoints the location of the dead animal and collects the remains.

Surgical procedure for successfully implanting the capsules depends to some extent on careful administration of anesthesia. Metofane[2] is administered initially in a closed cage, then during the operation as needed, using a nose cone. The incisions in the skin, muscle wall, and peritoneum are made just large enough to slip the capsule in (fig. 6); sutures are then placed separately in the muscle wall and skin.

Figure 6. — Inserting the transmitter into the peritoneal cavity.



[2]Metofane, brand of methoxyflurane, inhalation anesthetic, Pitman-Moore Division of Dow Chemical Company.

## Responses by P. Leucopus to Transmitter Implant

The first implants were subcutaneously located just left of the dorsal midline between the shoulders in two adult, 21 g specimen *Peromyscus leucopus*. One of these implants was expelled after 8 days, while the other remained for 16 weeks.

Six intraperitoneal (IP) implants were then made. Of these, one was a failure, one animal was sacrificed and examined, and the four remaining mice have shown no noticeable abnormality after 42 weeks. Examination of the sacrificed mouse disclosed no visible tissue irritation after 12 weeks of implantation. The unsuccessful IP implant involved an 8.1-g juvenile, which died 5 days after the operation. Cause of death was not determined, but no lesions or visible signs of irritation were found in the peritoneal cavity. Weights of the five successfully implanted mice ranged from 12 to 19 g.

## Discussion

Extensive biological testing is planned to elucidate any subtle effects of the implant on *P. Leucopus*. A preliminary test of the basic system was conducted on a ½-acre island from November to December 1971. During this time, signals were received from two mice; and their remains were recovered. No attempt was made to determine the cause of death.

The general system outlined here for obtaining mortality data on small mammals is sufficiently feasible to warrant further development and implementation. This system is being evaluated through further laboratory tests and field trials.

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by Francis M. Rushmore

# Techniques for CALLING SAPSUCKERS and finding their nesting territories

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NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Author

FRANCIS M. RUSHMORE, research forester, was graduated from the Forestry School of Pennsylvania State College in 1939. After 5 years of active duty in the Army, he joined the Northeastern Forest Experiment Station in 1946 and worked in forest-economics studies in several states. His research in silviculture included work in Maryland from 1947 to 1950, in New York from 1950 to 1961, and in Maine since 1962. His major interests have included silvicides and recreation research, research cooperation, and work with conservation organizations. He specialized in the study of wild animal damage and its relationship to forest trees from 1962 until his death on 30 May 1973.

# Techniques for **CALLING SAPSUCKERS** and finding their nesting territories


## ABSTRACT

In 9 years of study in Maine, the author developed a survey method for estimating populations of yellow-bellied sapsuckers (*Sphyrapicus varius varius* L.) and delineating their territories. The birds were attracted for study by tapping hardwood dowels to imitate noises the birds make in drumming and feeding.


THE YELLOW-BELLIED SAPSUCKER (*Sphyrapicus varius varius* L.) nests in many woodlands in the northern United States and Canada, its summer range extending nearly coast to coast (*Howell 1952 : 240*). Although we have some information about the sapsuckers' feeding habits related to tree sap and bark, we know much less about the benefits they may provide by feeding on insects that harm trees, and we do not fully understand the sapsuckers' place in forest ecology.

To gain that understanding, we first must know how to find sapsuckers easily so they can be studied. Nine years (1964 to 1972) of development, testing, and application of sapsucker calling and surveying techniques have provided efficient methods for finding sapsuckers in their northern nesting territories.

My objective is to describe those techniques and the results of a survey made with them in 1966. Some brief explanations of sapsucker behavior and territorial requirements will assist in understanding how sapsuckers react to imitations of their drumming and feeding sounds.

In 1964, I began developing sapsucker calling and surveying techniques based upon imitations of their drumming and feeding sounds. In 1966, I tested the techniques in Maine. Although only that study will be described in detail, some applications after 1966 suggest future uses for the techniques, and also help verify the results of the 1966 study. I used the same survey course from 1966 to 1971 for an annual population census; sapsuckers occupied 16 of the same 23 territories every year, 6 territories were occupied 5 years, and 1 territory was occupied 4 years *(unpublished data)*.

In 1970, I adapted the techniques for pesticide monitoring near Oxbow (lat. 46° 26′ N.), Aroostook County, Maine, where 74 sapsuckers served as indicators of the effects of Accothion on birds during a 210,000-acre spruce budworm spraying project. (The use of trade names does not constitute official endorsement by the U. S. Department of Agri-

culture.) Sapsuckers proved to be an ideal species for monitoring *(Rushmore 1971)*. In 1972, I monitored 103 sapsuckers in the same area, when Zectran was used on a 500,000-acre spruce budworm spraying project *(unpublished report)*.

The survey techniques were used by another person in 1970 to begin a sapsucker population census in New Brunswick, Canada. And I have taken many photographs of sapsuckers, found by calling, at their nests and feeding trees. This and other work is included in the 1,552 hours that I have spent observing sapsuckers and their behavior within their nesting territories, during the summers of 1964 through 1972; and it supports my confidence in these techniques.

## METHODS

### Drumming Imitations

Several authors have reported that sapsuckers can be called by imitating their normal drumming. Saunders *(1929 : 451)* found that sapsuckers drummed in response when he rapped a stick on a tree stump. Bent *(1939 :* calling three sapsuckers by rapping a foun-*128)* described Wendell Taber's experience in calling three sapsuckers by rapping a fountain pen on a dead tree. Howell *(1952 : 246, 267)* imitated drumming to attract yellow-bellied sapsuckers of the three western races. Lawrence *(1967 : 34)* used a small rock or the end of a pencil to imitate drumming. I also briefly outlined my techniques *(Rushmore 1969 : 5 and 1971 : 89)*. All of these imitations of the loud, normal drumming are basically similar. None of those reports fully describes a systematic survey technique or imitations of other sounds.

Although a wide variety of objects can be used to imitate the drumming, I used two 1-inch hardwood dowels, one 18 inches long, the other 7 inches. These sizes were convenient to use, they produced a desirable tone, and they induced sapsucker responses at long distances. I put a screw-eye into the end of each stick and fastened them together with a 2-foot length of cord. With the cord looped over my belt, the sticks were ready for use when needed, but could be dropped quickly when binoculars were used.

To imitate the loud. normal drumming of an adult male sapsucker, I held the larger dowel vertically about 4 inches from the top, between the thumb and one finger, and struck it about 6 inches from its bottom with the small stick, held at one end.

Sapsucker drumming can be distinguished easily from the drumming of other woodpeckers, because only the sapsucker uses the slower, spaced taps at the end *(Saunders 1929 : 451)*. To imitate the male's loud drumming, I made a series of hard, short rapid taps lasting about 1 second, with a few slower, louder, spaced taps at the end, like this:

. . . . . — — — — —

The time, length, and number of taps can vary widely and still produce good results. A series of these drummings at one location generally are required to get a response. The sequence that I used was to drum about 5 seconds and pause 10 seconds, then repeat that series 3 more times. If no response was received, I paused 1 minute and then repeated the first sequence. Then paused 2 minutes and — if there had been no response — repeated the first two sequences. These four sequences required about 8 minutes. First responses often occurred during the pauses.

### New Imitations

I had planned to use only the imitation of the loud, normal drumming for my study, but I developed three new imitations in April and May 1966 which substantially improved the survey efficiency. These were different from drumming; I was not aware of any earlier use of them. Sapsuckers are highly attracted to imitations of their feeding or drilling on live bark. The bark-feeding taps have a much softer tone than drumming, and they occur in short series of very rapid taps, often around the inside edges of existing sap holes. This tapping may be illustrated as:

. . . . . . . . . . . . . . . . . . . .

The bark-drilling is louder and slower than the bark feeding, but much softer in tone than drumming. These sounds are easily imitated with the same sticks, but the larger dowel is

held with the full hand to reduce the resonance, and much less force is used than when drumming.

Better response was also obtained from some very reluctant birds by imitating two birds. Since the drumming spots chosen by males and females often vary in resonance, it is easy to imitate two birds by varying the resonance of the imitation. To do this, I first imitated the male's loud drumming as previously described. Then I immediately grasped the stick with the full hand at the same place and produced a softer, shorter drumming of the same pattern. This muted drumming imitated the second bird.

In general, I used the male's loud, normal drumming for the first 4-minute sequence at each station. If more calling was needed, I tried a combination of drumming and the male's muted bark-feeding imitations. When a sapsucker came within 200 feet, but would not approach my loud drumming, the feeding imitation generally brought it to within 50 feet. Then, using the dowels, or softly tapping a pencil or pen on the metal of my binoculars to imitate a feeding or drilling sapsucker, I could generally bring the bird closer and into good position for positive identification — without requiring me to approach the bird and risk frightening it. Some extremely reluctant birds required the reassurance provided by one or two soft, normal drummings mixed with the feeding imitations.

### Finding Sapsucker Territories

Finding sapsucker territories is the key to intensive long-term study of these birds on their nesting range. For this study I defined a sapsucker territory as the area one pair of adult birds will occupy, nest in, feed in, and defend for at least one nesting season. The approximate boundaries are established well before the incubation period; and the adult sapsuckers will aggressively defend the territory and its major feeding trees by evicting non-family adult sapsuckers, at least during the period between nest-hole completion and the time migrant sapsuckers begin arriving in the fall.

Although there are some differences, this definition is essentially in agreement with Lawrence's *(1967 : 32)* "woodpecker territorial unit." In my study I included as territory that part of the range that contained major feeding trees and was defended against other sapsuckers and my imitations.

On 20 and 21 April 1966, I laid out six survey lines on the Penobscot Experimental Forest (lat. 44° 50′ N.), near Bradley, Penobscot County, Maine. The forests in this area generally contain a mixture of conifers and hardwoods, in a wide range of tree sizes and stand densities. The lines varied in length from 2,000 to 6,400 feet and totalled 5 miles; they were on gravel or logging roads, all within woodlands, and were well distributed throughout the 4,000-acre forest.

The area I considered to be covered effectively by the survey was 400 feet each side of the lines. Sixty census stations were located at 400-foot intervals along these lines, and they provided a 12-percent survey of the forest. Each station was visited eight times in 1966, twice during each of four periods: 2 to 18 May (in the pre-nesting period); 3 to 16 June (in the nesting period); 19 July to 2 August (after nesting); and 22 August to 2 September (before migration). Intensive observations also were made within some individual territories on other dates.

At each visit to a station, drumming and feeding sounds were imitated as previously described. Sapsucker responses were recorded on a new field-data map for each station; maps made earlier were not reviewed in the field. Preprinted maps permitted fast recording. The station was in the center of four circles spaced 100 feet apart; a line through the center represented the road and served to orient the map. A line was drawn from my position to each new estimated position of a responding bird. The estimated distance and direction, the time, the manner of response (drum, call, or silent approach), and age and sex of the bird, if determined, were all recorded for birds either heard or observed. About 3½ hours were needed for one round trip over each mile of survey line.

Survey work generally was done between 0830 and 1600 hours, Eastern Daylight Saving Time. Binoculars used were 8.5 x 44. While

at the stations I used no concealment or special clothing. I stood at the road edge, and in shade if it was available.

## RESULTS AND DISCUSSION

### Sapsucker Response to Imitations

I estimated the population of sapsuckers in the survey strips to be 138 birds: 2 adults and an estimated 4 juveniles in each of 23 territories. These birds responded to imitations of drumming and feeding sounds 341 times — counting a bird only once each trip. Adults responded 237 times and juveniles 104. Adults included 77 males, 50 females, and 110 whose sex was unidentified. Juveniles included 26 males, 59 females, and 19 whose sex was unidentified. Some juveniles that I recorded as females might have been males without red on their throats, but all juveniles recorded as males had red on their throats, as commonly occurs even on some nestlings in this region.

Sapsucker response to imitations varied with the seasons. Within the 23 best territories, on all 8 trips over the survey lines, I obtained responses from adult or young sapsuckers during 61 percent of the visits. The percentages of responses obtained during the four seasons were: pre-nesting 87, nesting 61, post-nesting 54, and pre-migration 41.

Response of both males and females was good from the time the birds arrived in the spring until actual nesting began, then responses steadily decreased. During incubation of the eggs, neither the male nor female was available for response while in the nest. The bird outside frequently was busy obtaining food before its next turn in the nest and generally required more coaxing before it would respond to imitations.

In known territories where I had not obtained a response on a particular day, it was easy to enter the territories later and find the birds by using the imitations, or by going to the nest or a feeding tree that I had found earlier. This verified that they had been present but refused to respond.

This apparent lack of concern did not extend to the actual encroachment of strange sapsuckers. I saw many aggressive territorial defenses during all seasons, and strong defense continued until migrant sapsuckers began arriving in the fall. Only then were strange adult sapsuckers tolerated within the territory, and only on the sap trees not being used by family members. Occasionally, before migration, juvenile sapsuckers that had strayed from an adjacent territory within several weeks after fledging were tolerated within a territory, but they were driven from sap trees being used by family members. Even the local juveniles participated in this defense. This is best observed when the local juveniles are color-banded *(Rushmore 1971)*.

The increasing independence of juvenile sapsuckers sharply increased their response to imitations by late July. (Earlier, adults commonly drove their juveniles away from my imitations, often with vigorous attacks.) When I was within a territory, there generally was at least one juvenile that quickly left the sap-tree area and came to my imitations. That response was very helpful during my 1970 and 1972 pesticide monitoring, when I wished to verify the survival of color-banded juveniles *(Rushmore 1971 : 98)*.

The weather also seemed to have some influence on responses. Fewer responses were obtained when strong winds whipped tree branches together and made excessive noise. Then I could not hear birds unless they were close. Heavy rain and snow seemed to reduce responses on 9 May when some sapsuckers took shelter in old sapsucker nests. Warm, gentle rain and calm wind did not seem to deter responses. At temperatures well above 80°F, birds seemed to be less active; otherwise, temperature and cloud cover seemed to have little effect on the responses I observed.

Supplemental observations suggested that best response after midsummer may be obtained from about 0600 to 1000 hours EDT. Early spring drumming and calling among sapsuckers, unprovoked by imitations, appeared to occur at peak intensities on calm, sunny days, and those were optimum for surveys. Some birds may have been missed on surveys made during strong wind and rain, and these generally required another trip over a line.

### First Responses

Sapsuckers make two distinct calls. Most frequently heard was a call that to me resembled *CREE*; it was usually repeated several times. It often was used by unsuspecting birds to answer my drumming. Birds using it generally responded further. The other call resembled a drawn-out *CAY*, given when they were alarmed. Birds voicing it sometimes would not respond further to imitations of any kind; but if they did, the drilling and feeding imitations worked best.

Throughout the survey the most frequent first response among 237 birds was calling: 49 percent responded by calling, 28 percent by drumming, and 23 percent by coming without either calling or drumming. Most of the drumming response occurred in the pre-nesting season, when it exceeded calling. Later, calling exceeded drumming. Most of the silent approaches occurred during the pre-migration season.

Among 192 adults that made their first response by drumming were 56 males, 18 females, and 118 whose sex I could not determine. I saw only four juveniles drum in response to my imitations; their responses occurred 29 July and later; one of these juveniles was female and one male; I could not determine the sex of the other two. Birds responded more by calling. Drumming often required a flight to a known drumming place.

### Calling Birds Nearer

Among 257 sapsuckers that responded, I called 70 to within 100 feet, and many of them came much nearer — often to within 20 feet or less. Of the 189 adults, 120 came; of the 68 juveniles, 60 came within 100 feet. Birds that responded repeatedly but would not leave their territory and come to the stations could easily have been approached.

Adults were first seen at distances averaging about 180 feet and were called to within distances averaging 40 feet. For juveniles these distances were about 120 and 35 feet. Many of the adults in the 23 territories soon were called to within 100 feet. The first trip in early May brought in 43 percent of the females and 56 percent of the males. After the second trip in May, 74 percent of the females and 91 percent of the males had come within 100 feet.

My imitations of feeding and drilling sounds were more effective for bringing sapsuckers close to me than was the imitation of their loud normal drumming. Among 162 sapsuckers that I called to within 100 feet, 82 percent came to the feeding-drilling imitations, 16 percent came to the loud drumming, and 2 percent came to the muted drumming.

The feeding and drilling imitations seemed to convince sapsuckers that another sapsucker was nearby. They often came within 30 feet and searched the lower trunks of 10 or more trees in a circle around me, and they would return repeatedly if the feeding imitations were used as they started to leave. It was not unusual for a bird to fly directly toward me and then zoom off when about 5 feet away; I assumed they believed another sapsucker was at my location, even when I was not near a tree. My lack of concealment did not seem to deter them — until after they had searched the trees — provided I did not move except to make the imitations when the birds did not see my movements. Imitations of bark feeding were especially useful for bringing reluctant birds close, to induce responses late in summer, and to coax birds into position for easy observation and identification.

### Territories Found

Sapsucker responses revealed feeding, nesting, and defense locations within their territories, but allowed only approximate estimates of territorial boundaries. That estimate was made later by making a composite map from the information on the eight maps for each station; the number of response locations averaged 27 per territory and varied from 13 to 52. Enclosing these locations with a line gave a rough estimate of the territory boundaries.

These survey techniques do not enable an observer to remain at stations and precisely identify all territorial boundaries. But after a territory has been found, it can be entered for more intensive studies, and I later verified the boundaries of several territories that way. Often the conflicts between sapsuckers from two different territories indicated boundaries that later proved to be very stable — even for several years. My imitations frequently

seemed to perpetuate those conflicts, especially in early spring before the birds had settled their boundary disputes.

Sapsucker territories occupied about 47 percent of the survey strips. An unoccupied buffer zone occurred between each of 21 territories and the adjacent one, and the buffer generally was at least as large as a territory. The other two territories were separated only by a road, which served as a boundary for the same male (banded) for at least three years; adverse habitat surrounding these territories apparently forced this crowding.

The 23 territories were at least partly within the survey strips. Nineteen of the 23 final territories were found on 20 and 21 April 1966, by using a 4-minute drumming sequence at each station during survey line establishment. However, I withheld final judgment of the approximate territory location until after all eight trips over the survey lines had been completed on 2 September 1966. Four more territories, well beyond the 800-foot strips, were occupied, but I discarded them when reliable responses were no longer obtained in late summer; that is typical of distant birds.

The existence of all 23 territories became apparent during the first two trips over the survey lines in May. No new territories were found after that, and I believe these were the only territories that occupied part of the 800-foot survey strips. As noted earlier, 16 of these same territories were occupied every summer during the 6-year population census that followed this study.

The 23 territories averaged about 7.6 acres in size, and their approximate dimensions were 720 by 460 feet. That acreage agrees reasonably well with Lawrence's *(1967 : 31)* "territorial ranges" of 5.1 and 5.4 acres. My territories generally were smaller when the habitat or adjacent sapsuckers compelled crowding of adults, and territories normally were larger when there was less competition. Similar situations occurred in Aroostook County, Maine, in 1970 and 1972 *(Rushmore 1971; unpublished report 1972)*.

There was a common reaction to my imitations that helped identify a territory boundary. Before nesting, some sapsuckers would leave their territories, come part of the distance toward me, and challenge my drumming. Then they normally would retreat as I came closer and drummed, and they would stay and defend only within their territories.

These defenses were aggressive and included close approaches to my imitations. My drumming frequently went unchallenged when 800 or more feet from known territories, then would be challenged promptly at about 400 feet. The same birds occasionally would come to several stations within their territory, their approach being traced by frequent responses recorded on maps.

Unmated birds, and mated birds in territories with unsettled boundaries, often came farther than did well-established or paired adults. For example, an apparently unmated male followed my drummings for 1,200 feet on 28 April 1966. On 7 May 1968, an apparently unmated female, with all the adult markings, except that she had no red on her head, followed my drummings for 1,600 feet, the longest distance I have recorded. These are exceptionally long distances, but similar actions occur with enough frequency so that an observer should be aware of them. These actions are easily identified when they occur, because the birds drum or call frequently and reveal their routes from one station to another.

### Response of Other Woodpeckers

Other species of woodpeckers occasionally responded to my imitations of sapsucker drumming. Their responses included drumming and gradual approach. I have seen and heard the normal drumming of our five other common woodpeckers, and these differed from the drumming of the yellow-bellied sapsucker in speed, loudness, or drumming-place selection; and they did not include the sapsuckers' spaced taps at the end.

Occasionally, I saw and heard sapsuckers omit those spaced taps, but normal drumming soon was resumed. I have never seen another woodpecker use the spaced taps as an ending, and that is a key element of this survey technique. When the taps occurred, I was confident that it was a sapsucker — no matter how far away it was, nor whether I saw the bird.

Sapsuckers were the most abundant woodpeckers I observed on the study area, accounting for 82 percent of the 348 woodpecker observations. Among the other woodpeckers were 9 percent flickers *(Colaptes auratus)*, 6 percent hairy woodpeckers *(Dendrocopus villosus)*, 1.5 percent downy woodpeckers *(Dendrocopus pubescens)*, and 1.5 percent pileated woodpeckers *(Hylatomus pileatus)*. The few arctic three-toed woodpeckers *(Picoides arcticus)* were observed when sapsuckers were not present; these were not included in this summary.

### Drumming Versus Birding

Although I did not originally plan to compare the drumming technique with other techniques, I did record sapsuckers observed while making my silent return trips along each of the survey lines. This provided a basis for only a rough comparison of the drumming and birding techniques, because I walked faster than normal during birding, and I spent more time on the survey. However, my silent return trips never located as many sapsuckers as the imitations had. Birds seldom came close enough or stayed long enough to be fully identified. My imitations located 2½ to 9 times more adult sapsuckers.

Even during the spring drumming season it is common for sapsuckers to do no voluntary drumming for periods of several hours. Therefore, an advantage of these techniques is that they permit observation of sapsuckers at the time an observer wants them. Many more sapsuckers can be located in a short time than would be possible by depending on the birds' unprovoked sounds or actions.

The calling and surveying techniques should prove useful in sapsucker studies of many types. They should be especially helpful in activities such as pesticide monitoring, population census, banding, photography, birding, and national programs such as the Breeding Bird Census and North American Nest Record Card Program.

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by G. R. Trimble, Jr.

# The Regeneration of Central Appalachian Hardwoods With Emphasis on the Effects of Site Quality and Harvesting Practice

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Author

G. R. TRIMBLE, JR., is timber-management project leader for the Northeastern Forest Experiment Station at its Timber and Watershed Laboratory at Parsons, West Virginia. He received his forestry training at the University of Maine. He worked for a number of years in watershed management research both in West Virginia and New Hampshire and has worked on forest-management problems throughout most of the Northeastern States.

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## ABSTRACT

This report is an attempt to integrate and summarize research results from studies made mostly in West Virginia and to show the relationship of site quality and cutting practices to hardwood reproduction, with special emphasis on species composition. Reproduction has been found satisfactory in numbers and distribution after both clearcutting and selection cutting, but the species composition differs greatly; shade-tolerant species predominate after selection cutting, but generally a good proportion of the regeneration that follows clearcutting will be composed of intolerant species — depending somewhat on the density of advance reproduction and the abundance and species composition of stump sprouts. Site quality influences the species composition of reproduction after cutting, and the effect is greater with clearcutting than with selection cutting. After clearcutting, on the excellent sites we can expect a good representation of yellow-poplar and black cherry; and on the fair sites we can expect a variable number of oak stems. After selection cutting, we get beech and sweet birch on both sites with sugar maple predominant on the excellent site and red maple better represented on the fair site. When group selection or patch cutting is the reproduction method, and where the objective is a good species mix including some intolerants, results of research suggest that openings should be at least ½ acre and preferably 1 acre. Some factors other than site quality and cutting practice that affect the nature of regeneration are: species composition of the overstory, season of cutting, density of low vegetation, presence of grapevines, and damage by spring frosts.

# The Regeneration of Central Appalachian Hardwoods With Emphasis on the Effects of Site Quality and Harvesting Practice

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## INTRODUCTION

THIS IS A REPORT of results from research and observations made mostly on the Fernow Experimental Forest near Parsons in northern West Virginia. Many of the data were generated by long-range research—in some instances as long as 20 years. Where appropriate, data from other areas are used to expand or substantiate results from Fernow studies. In the main, this is a summary and integration of information already published piecemeal in a number of other sources.

In evaluating the information presented here, the reader should keep in mind that deer browsing on the Fernow or in most of West Virginia is not a serious deterrent to obtaining satisfactory reproduction, as it is in many hardwood forest areas. On the Fernow, only about 3 to 4 percent of the woody stems are browsed each year; and the deer herd probably does not exceed 15 animals to the square mile (*Cromer and Smith* 1968). Moreover, because of the dispersion of cutting operations, deer browsing is not concentrated.

## DESCRIPTION OF THE FERNOW EXPERIMENTAL FOREST

The Fernow Experimental Forest, a 3,640-acre tract on the Monongahela National Forest, is an outdoor laboratory for studies in managing mountainous forest land. The forest stands here are second-growth hardwoods dating from around 1905, when heavy cuttings were made, with a varying admixture of old-growth stems. In topography, history of cutting, climate, and variety of species, the Fernow Forest is representative of much of the timberland in West Virginia and adjacent states.

Almost all Fernow soils are well-drained, medium-textured loams and silt loams. Most are derived from sandstone and shale, but some excellent sites are underlain by limestone. Average soil depth is about 3 feet. Based on site index, almost all areas on the Fernow can be rated as fair, good, or excellent. These designations correspond to oak site indexes 60, 70, and 80 feet plus.

In this hardwood forest, upland oaks are the most common species group. Northern red oak, which is found on all sites, is most abundant. Chestnut oak and white oak are the next most abundant oaks. These two species, although seldom found on the excellent sites, are more common than red oak on the fair sites. Scarlet and some black oak can also be found on fair sites.

Sugar maples are numerous on all but the fair sites, and beech covers the site range but is most frequent on the good sites. Yellow-poplar makes up a large part of excellent and good site stands, along with black cherry, white ash, hickory, and basswood. Scattered trees found in mixture on the better sites include yellow birch, cucumbertree, butternut, and elm.

Red maple, black locust, sweet birch, and—to a lesser extent—Fraser magnolia are consistent but generally minor components of the forest on all sites. However, these species are more common on the good and fair sites. Black gum, sassafras, and sourwood are fair-site trees of little commercial importance.

Among the scrubby tree species are flowering dogwood, pin cherry, striped maple, eastern hophornbeam, and downy serviceberry.

## GENERAL CONSIDERATIONS

Most of the study results summarized here were obtained on areas that ranged in size from 2 to 80 acres. The major variables whose relationships to reproduction are reported are site quality and cutting practice.

Site quality was expressed for each area on the basis of average oak site index *(Schnur 1937)* taken from grids of site-measurement points. Although site quality is a continuous variable, it is not subject to precise measurement; and it is usually expressed for convenience as a discrete variable (generally by 10-foot site-index classes), thus weakening the true expression of its real relationship to reproduction.

Cutting practices were expressed in the context of harvesting systems such as clearcutting, individual-tree selection cutting, and diameter-limit cutting.

In Appalacian hardwood stands, the quality of the site is strongly expressed in the species that predominate in stands originating from the same type of cutting. For example, yellow-poplar is abundant after clearcutting on excellent sites, but it is rarely found on poor sites. And chestnut oak, while abundant on poor and fair sites, is sparse on excellent sites. It is generally considered that the more demanding species in terms of moisture and nutrients are better competitors on good sites but compete less successfully with the less-demanding species on sites of low moisture or nutrient status.

The influence of cutting practice is strongly expressed through its effect on the amount of light that reaches the forest floor and the understory vegetation. Because different species of trees react differently to different light intensities, the degree of overhead canopy removal has a strong effect on the species that germinate, develop, and grow. The key to evaluating light effects is the inherent shade tolerance of the species involved. The term as used here refers to the ability of the plant to survive under deep shade. As examples of different species tolerance, sugar maple is considered to be very tolerant, and black locust is rated as very intolerant. The tolerance of a given species is known to vary. Baker *(1950)* said that young trees are more tolerant than old trees; trees growing on moist, rich soils seem to be more tolerant than the average of the species; and tolerance seems to be greater in the southern part of the range of a tree.

A number of other variables whose influences have only weakly or indirectly been measured—if measured at all—also affect the establishment and development of reproduction, and some of these are discussed.

## THE NATURE OF REPRODUCTION

### What is the Nature of Advance Reproduction Before Cutting?

Because advance reproduction may have the potential to form a large part of the new stand after cutting, it is important that we have good information about it. Depending on the objectives of management and on the characteristics of this advance reproduction, we may elect to rely on it for the next crop, or we may decide to destroy all or selected components of it so that more desirable stems may take its place.

For over 20 years, we have been examining advance reproduction under undisturbed middle-aged hardwood stands on excellent, good, and fair sites on the Fernow Experimental Forest. In addition, we made a reproduction survey in conjunction with an oak site study, which covered undisturbed sawtimber stands in north-central West Virginia and western Maryland *(Weitzman and Trimble 1957)*.

#### Abundance and Distribution

Before cutting, all previously unmanaged stands on the Fernow Experimental Forest contained advance reproduction (tables 1 and 2). Considerable variation existed between stands in number of both large (1.0 inch to 5.0 inch dbh) and small (1 foot tall to 1.0 inch dbh) reproduction stems. Tight uniform stands had sparse reproduction, but stands

Table 1.—*Reproduction before logging—commercial species*
[From Trimble and Hart 1961]

| Site quality | Original[a] basal area per acre | Area[b] | Stems per acre (average) | Mil-acres stocked | Five most abundant species by percent of total stems | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| | *Sq. ft.* | *Acres* | *No.* | *Pct.* | SMALL REPRODUCTION[c] | | | | |
| Excellent | 126 | 143 | 1,300 | 59 | Sugar maple 42% | Beech 32% | Sassafras 8% | Red maple 4% | E. hophornbeam 3% |
| Good | 109 | 317 | 2,100 | 72 | Sugar maple 52% | Beech 25% | Sassafras 8% | Hickory 4% | Red maple 3% |
| Fair | 117 | 88 | 3,400 | 79 | Sassafras 33% | Chestnut oak 19% | Sugar maple 14% | Red oak 9% | Red maple 8% |
| | | | | | LARGE REPRODUCTION[d] | | | | |
| Excellent | 126 | 143 | 410 | — | Sugar maple 31% | Beech 28% | Sweet birch 13% | Red maple 10% | White ash 4% |
| Good | 109 | 317 | 410 | — | Sugar maple 40% | Beech 21% | Sweet birch 12% | Red maple 7% | Red oak 4% |
| Fair | 117 | 88 | 430 | — | Red maple 26% | Sugar maple 12% | Red oak 11% | Beech 9% | Chestnut oak 9% |

[a]In trees over 5.0 inches dbh.
[b]These are total acreage figures for the respective categories. Each is a summation of several cutting areas.
[c]Stems ranging from 1 foot tall to 1.0 inch dbh, measured on milacre plots.
[d]Stems ranging from 1.0 to 5.0 inches dbh, measured on 1/100-acre plots.



Table 2.—*Reproduction before logging—commercial species*
[1972 data]

| Site quality | Original[a] basal area per acre | Area[b] | Stems per acre (average) | Mil-acres stocked | Five most abundant species by percent of total stems | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| | *Sq. ft.* | *Acres* | *No.* | *Pct.* | SMALL REPRODUCTION[c] | | | | |
| Excellent | 141 | 35 | 1,600 | 38 | Sugar maple 69% | E. hophornbeam 10% | Beech 9% | Basswood 6% | Fraser magnolia 3% |
| Good | 112 | 34 | 4,000 | 74 | Sugar maple 67% | White ash 7% | Hickory 5% | Red maple 4% | Red oak 3% |
| Fair | 107 | 29 | 2,100 | 85 | Sassafras 34% | Chestnut oak 20% | Red maple 14% | Red oak 9% | Sugar maple 6% |
| | | | | | LARGE PRODUCTION[d] | | | | |
| Excellent | 141 | 35 | 148 | — | Sugar maple 69% | Beech 18% | E. hophornbeam 7% | Red maple 3% | Basswood 2% |
| Good | 112 | 34 | 307 | — | Sugar maple 54% | Red maple 17% | Hickory 6% | Beech 3%+ | White oak Red oak Each 3%− |
| Fair | 107 | 29 | 333 | — | Red maple 34% | Sourwood 13% | Sugar maple 9% | Sweet birch 8% | Beech 7% |

[a]In trees over 5.0 inches dbh.
[b]These are total acreage figures for the respective categories. Each is a summation of several cutting areas.
[c]Stems ranging from 1 foot tall to 1.0 inch dbh, measured on milacre plots.
[d]Stems ranging from 1.0 to 5.0 inches dbh, measured on 1/100-acre plots.

whose canopies were broken up by heavy losses of the chestnut component or older residual trees had more reproduction. This relationship conforms to the findings of Bowersox and Ward *(1972)* who, on the basis of a study on intermediate sites in Pennsylvania, concluded that basal area density was negatively correlated with the development of acceptable advance reproduction and that stand age was positively correlated.

Small stems were considerably more numerous than large stems; in most stands several thousand small stems per acre contrasted to several hundred large stems per acre.

In general, an inverse relationship seemed to exist between the abundance of reproduction and site quality. This can probably be attributed to lower overstory densities on the poorer sites.

The percentage of sampled milacres that were stocked with at least one stem of commercial species was used as a measure of distribution of stocking. Distribution was measured only for the small reproduction class. As with abundance, it was better on sites of lower quality. On the excellent sites, average milacre stocking (tables 1 and 2) was 38 to 59 percent; on the good sites, it was 72 to 74 percent; and on the fair sites, it was 79 to 85 percent.

## Species Composition

Most of the reproduction in both small and large classes, consisted of species that rated very tolerant and tolerant (table 3): sugar maple, beech, eastern hophornbeam, and red maple. Some species, particularly on the fair

Table 3.—*Tolerance ratings*[a]

| Species | Tolerance rating | | | | |
|---|---|---|---|---|---|
| | Very tolerant | Tolerant | Intermediate | Intolerant | Very intolerant |
| Eastern hophornbeam | X | | | | |
| American beech | X | | | | |
| Sugar maple | X | | | | |
| Flowering dogwood | X | | | | |
| Red maple | | X | | | |
| Basswood | | X | | | |
| Black gum | | X | | | |
| Sweet birch | | X[b] | | | |
| Fraser magnolia | | | X[d] | | |
| Cucumbertree | | | X[d] | | |
| White ash | | | X | | |
| Basswood | | | X[b] | | |
| Black gum | | | X[b] | | |
| Yellow birch | | | X | | |
| Sweet birch | | | X | | |
| White oak | | | X | | |
| Northern red oak | | | X | | |
| Black oak | | | X | | |
| Chestnut oak | | | X[c] | | |
| Slippery elm | | | X[b] | | |
| Hickories | | | X[b] | | |
| Downy serviceberry | | | X[b] | | |
| Sourwood | | | X[b] | | |
| Scarlet oak | | | | X[c] | |
| Butternut | | | | X | |
| Hickories | | | | X | |
| Yellow-poplar | | | | X | |
| Sassafras | | | | X[d] | |
| Black cherry | | | | X | |
| Bigtooth aspen | | | | | X |
| Black locust | | | | | X |
| Pin cherry | | | | | X[b] |

[a]From Baker *(1950)* unless otherwise noted.
[b]Local observation.
[c]Silvics of Forest Trees of the United States *(USDA 1965)*.
[d]Great uncertainty *(from Baker)*.

sites, rated borderline between tolerant and intermediate or rated intermediate: basswood, sweet birch, hickory, white ash, chestnut oak, red oak, and Fraser magnolia. One species, sassafras, a rated intolerant that is quite tolerant when young, was plentiful in the smaller size classes, but died out before it reached an inch dbh.

Under a closed canopy, most of the stems that reach large reproduction size on the excellent and good sites are of the very tolerant and tolerant species (tables 1 and 2). As site quality declines, more species of intermediate tolerance, most important the oaks, survive to grow beyond the 1.0-inch dbh threshold.

This relationship confirms the findings of Weitzman and Trimble *(1957)* in a survey of well-stocked stands containing a minimum of 32 percent of oaks in the overstory. They found that natural oak reproduction, like the distribution of oak trees, is more prevalent on the medium to poor sites. This provides a clue to the sites on which oak may be able to maintain itself. In the stands they sampled, oak formed a decreasing proportion of the total reproduction as site quality improved. At about site index 65, oak reproduction dropped from first place. On site index 80, only 3 percent of the total established reproduction was oak.

Weitzman and Trimble *(1957)* reported that:

- At site index 60, 26 percent of established reproduction was oak and at site index 40, the percent rose to 47.

- On better sites, competition from faster-growing or more tolerant species makes conditons less conducive to the establishment of the oaks.

- A breakdown of oak reproduction by species . . . indicates that some oak reproduction occurs over a wide range of site quality; with red oak absent on the areas of lowest site index (40) and scarlet oak absent from the better sites (site index 70 and 80).

## How is the New Stand that Follows Cutting Related to Advance Reproduction?

### After Partial Cutting

Advance reproduction under unmanaged sawtimber stands is composed largely of tolerant species, particularly on the better sites. These species will germinate, hang on, and then grow when released. After selection cutting, many stems of sugar maple, red maple, and beech will develop into good candidates for crop trees *(Trimble 1965 and 1968)*.

On lower-quality sites, which have more open canopies, some stems of intermediates, such as most of the oaks and sweet birch, will persist for years; and a few of them may develop into merchantable trees after heavy partial cutting.

### After Clearcutting

Little work has been done to define the type of advance reproduction that survives clearcutting and develops to form a portion of the new stand. We know that many larger advance reproduction stems either survive the cutting and grow, or, if broken off, produce sprouts that develop and grow. In oak, at least, these sprouts grow much faster than comparable undamaged reproduction *(Sander 1966)*. About two-thirds of large advance reproduction stems are broken off in clearcutting *(Trimble and Rosier 1972)*.

We know from observations that an undetermined number of advance reproduction stems die in the first few years after sudden exposure. We know that some larger advance reproduction stems enter the dominant crown class of the new stand—although too high a proportion of them are branched and limby *(Trimble 1972)*. We suspect—based on considerable observation—that small stems (less than 2 to 4 feet tall) of suppressed reproduction of oak and sugar maple—and probably other species—cannot compete successfully with the flush of new plant growth that follows clearcutting.

From work done in the Central States, we know that on oak sites, the new stand will contain oak in proportion to the advance oak

reproduction on the area before the harvest cut *(Clark and Watt 1971)*. And we know, based on work done by Sander *(1972)*, also in the Central States, that the bulk of oak reproduction that makes acceptable growth after clearcutting comes from advance stems over 4.5 feet tall. On the other hand, some rated intolerants, such as black cherry and sassafras, are quite tolerant when young; and after clearcutting, small stems of these species can compete successfully for a place in the new stand.

## How Does Degree of Overstory Removal Affect Reproduction?

### Species by Site Quality

The degree of overstory removal has a definite effect on the species composition of the new stand. And this effect is variable according to site quality. Moreover, the numerical order of species will change with time from cutting.

In a publication on diameter-limit cutting *(Trimble 1971)*, a summation was made from data from a number of areas on the effect of degree of canopy removal on tolerant versus intolerant reproduction. The two extremes of canopy removal were clearcutting and selection cutting; diameter-limit cutting, in amount of residual basal area, fell between them but nearer to selection cutting than to clearcutting. The heavier the removal, the higher the proportion of reproduction that is of intolerant species. This is illustrated by the 7- to 20-year observations (table 4) on large reproduction. Intolerants made up 37 percent of these stems after clearcutting, 18 percent after diameter-limit cutting, and only 5 percent after selection cutting. Reproduction of tolerant species was in a reverse order: 27 percent for clearcutting, 62 percent for diameter-limit, and 78 percent for selection cutting.

Under selection cutting, in the immediate years after a harvest, there is a tendency for the seeds of some intolerant species to germinate and for the seedlings to grow for a while but then to die out. The life-long intolerants, like yellow-poplar, die soon; those species that are fairly tolerant when young, such as white ash and black cherry, persist longer but as they lose their early tolerance with increasing age and as the upper canopy closes, they too succumb. Thus it is misleading in predicting future stand composition to weigh too heavily reproduction counts of small stems.

The long-range reproduction trend is clear following light to medium selection cutting: maple, beech, hophornbeam, and sweet birch will predominate in the new stand *(Trimble 1965 and 1970)*. Sugar maple and beech will probably be most numerous on the excellent and good sites, and red maple and beech will dominate the fair sites. Sweet birch will be well represented on all areas.

From data for clearcut compartments on the good and excellent sites, we can expect to get a good representation of black cherry and yellow-poplar seedlings if viable seed is present. The actual proportions depend to a large extent on the amount of competitive advance reproduction—which is composed largely of

Table 4.—*Effect of cutting practice on the proportions of tolerant versus intolerant reproduction*

| Type of cutting | No. of areas | Total acreage | Site index (for oak) | | Number of 1- to 5-inch stems in— | | Stump sprouts as a proportion of total reproduction |
|---|---|---|---|---|---|---|---|
| | | | Range | Average | Intolerant species[a] | Tolerant species[b] | |
| | *No.* | *Acres* | *Ft.* | *Ft.* | *Weighted pct.* | *Weighted pct.* | *Pct.* |
| Clearcut | 9 | 110 | 61-77 | 70 | 37 | 27 | 58 |
| Diameter-limit | 5 | 151 | 59-75 | 69 | 18 | 62 | 18 |
| Selection | 7 | 198 | 59-82 | 71 | 5 | 78 | 18 |

[a]Includes the following very intolerant, intolerant, and intermediate species: red oak, yellow-poplar, black cherry, white ash, black locust, sassafras.
[b]Includes the following very tolerant and tolerant species: beech, sugar maple, red maple.

Table 5.—*Ranking of 1- to 5-inch stems of reproduction 7 years after clearcutting five most numerous species.*

[Numbers in parentheses are numbers of stems per acre]

| Ranking | Excellent site (S.I. 80 for oak) | Good site (S.I. 70 for oak) | Fair site (S.I. 60 for oak) |
|---|---|---|---|
| 1 | Sugar maple (91) | Black locust (124) | Red maple (186) |
| 2 | Basswood (49) | Sugar maple (111) | Sassafras (176) |
| 3 | Eastern hophornbeam (43) | Red maple (107) | Chestnut oak (103) |
| 4 | Black locust (38) | Sassafras (97) | Red oak (84) |
| 5 | Black cherry (27) | Yellow-poplar (75) | Sourwood (49) |

tolerant species—and on the age of the stand when cut. Clearcut young stands produce a lot of fast-growing, space-occupying stump sprouts.

On fair sites, yellow-poplar and black cherry appear infrequently; the most abundant intolerant is sassafras. We can usually expect a lot of red maple and oak stump sprouts. And if advance reproduction of oak is present—which it usually is—we can expect a good representation of oak seedlings and, more likely, seedling sprouts.

The reproduction tally on these clearcut areas indicates that species composition was strongly influenced by site quality, but a wide variety of species of all tolerance classes was represented on all sites and all study areas—a greater variety than found under selection cutting where a few tolerant species predominate. On two excellent sites, each about 35 acres, one of which had been cut three times by the selection system and the other had been harvested 12 years previously by clearcutting, tallies were made of 1 to 5 inch stems.

Twenty commercial species were tallied on the clearcut areas and 17 on the selection cut area. However, when the number of species containing 5 percent or more of the total number of stems were compared, the clearcut area had 7; but the selection cut area had only 3.

At 7 years on the clearcut compartment, the larger free-to-grow stems (table 5) were composed mostly of species that had at least one of the following characteristics: (1) great sprouting vigor (red maple, oak, and basswood); (2) shade tolerance, permitting a start under the old stand (sugar maple); (3) unusually fast early growth (black cherry, eastern hophornbeam, and sweet birch); and (4) a tendency to root sucker (black locust and sassafras).

Under a clearcutting system, the proportional relationship between tolerants and intolerants in the new stand is far from consistent because of the presence in varying numbers of tolerant advance reproduction and of stump sprouts, which together can make up an appreciable part of new stands after clearcutting.

On good and excellent sites under intensive even-aged management, advance reproduction will create something of a problem. Present indications are that a thick understory of tolerant species will develop in such stands as a result of thinnings and that this situation will have to be countered if a new stand of intolerants is sought after the clearcut harvest. If this advance reproduction is not over 15 feet tall, it can be controlled by an understory foliar spray a couple of years before the harvest cut *(Smith and Trimble 1970)*.

In sites of lower quality, where the desired species will probably be oak, the effect of properly designed late thinnings may be to encourage an understory of advanced oak reproduction and thus favorably influence the composition of the next stand.

Table 6.—*Ranking of 1- to 5-inch stems of reproduction 12 years after clearcutting, 5 most numerous species.*

[Numbers in parentheses are numbers of stems per acre]

| Ranking | Excellent site (S.I. 80 for oak) |
|---|---|
| 1 | Sweet birch (550) |
| 2 | Sugar maple (246) |
| 3 | Yellow-poplar (221) |
| 4 | Black cherry (145) |
| 5 | Eastern hophornbeam (114) |

The change in species composition with time from cutting cannot be defined accurately until more time has passed. Some switching in numerical order may take place after clearcutting, which is illustrated by a comparison of 12-year data (table 6) to 7-year data (table 5) for the excellent site clearcuts (data are not yet available for the good and fair sites). The big difference is the increasing proportion of sweet birch and yellow-poplar in the large reproduction class at 12 years as compared to 7 years.

We have good information on the growth and development of tolerant reproduction (sugar maple) under selection cutting *(Trimble 1965 and 1968)*, but comparable information following clearcutting is lacking. Several studies now under way should tell us how different species grow and develop over time after clearcutting on sites of different quality levels. When this information becomes available—in about 5 years—we will be better able to predict regeneration development.

### Abundance and Distribution

On the Fernow Experimental Forest, clearcutting has resulted always in an abundant, well distributed stand of reproduction. This has been true on all sites. Species composition has sometimes left something to be desired, but abundance and distribution can be rated as satisfactory, as shown by tables 7 and 8 *(Trimble 1972, Trimble and Hart 1961)*. Selection cutting, too, has produced a satisfactory number and distribution of understory stems (table 8), although they are composed mostly of a few tolerant species.

The Fernow data indicate that 7 to 10 years after cutting we can expect 5,000 to 10,000 stems of small reproduction and 300 to 800 stems of large reproduction per acre of commercial species under all types of commercial harvesting, with the actual number of stems roughly proportional to the degree of canopy removal. We can expect faster growth rates after heavy canopy removal; this is illustrated by the greater numbers of large reproduction after clearcutting (table 8).

We can expect good distribution of reproduction; more than 85 percent of the milacres should be stocked with small reproduction of commercial species under both selection cutting and clearcutting. For large reproduction, we found that 80 percent or more of all 1/100-acre plots were stocked with commercial species.

Table 7.—*Reproduction of commercial species after 7 growing seasons from clearcutting*

| Compartment number | Small reproduction (1 foot tall to 1 inch dbh) | | Large reproduction (1 to 5 inches dbh) | |
|---|---|---|---|---|
| | Total stems per acre | Proportion of 1/1000-acre plots stocked | Total stems per acre | Proportion of 1/100-acre plots stocked |
| | *No.* | *Pct.* | *No.* | *Pct.* |
| | EXCELLENT SITE | | | |
| 32 | 7,400 | 96 | 420 | 80 |
| 33 | 15,755 | 98 | 378 | 84 |
| 43 | 9,067 | 93 | 289 | 91 |
| Average | 10,741 | 96 | 362 | 85 |
| | GOOD SITE | | | |
| 36 | 6,223 | 91 | 926 | 96 |
| 37 | 4,333 | 91 | 790 | 100 |
| 39 | 7,400 | 96 | 907 | 100 |
| Average | 5,985 | 93 | 874 | 99 |
| | FAIR SITE | | | |
| 34 | 8,955 | 98 | 579 | 89 |
| 35 | 8,156 | 96 | 898 | 100 |
| 38 | 7,434 | 98 | 844 | 100 |
| Average | 8,181 | 97 | 774 | 96 |

Table 8.—*Commercial species: reproduction 5 and 10 years after logging in a well-stocked sawtimber stand on an excellent site, by intensity of cut.*

| Intensity of cut | Basal area cut | Original basal area per acre[a] | Small reproduction | | Large reproduction Per acre |
|---|---|---|---|---|---|
| | | | Per acre | Distribution[b] | |
| | *Pct.* | *Sq. ft.* | *No.* | *Pct.* | *No.* |
| 5-YEAR MEASUREMENTS | | | | | |
| Clearcut | 87 | 103.0 | 10,130 | 100 | 450 |
| Diameter-limit | 58 | 98.2 | 10,060 | 81 | 340 |
| Extensive selection cut | 48 | 103.0 | 8,130 | 87 | 290 |
| Intensive selection cut | 46 | 105.8 | 7,500 | 88 | 210 |
| 10-YEAR MEASUREMENTS | | | | | |
| Clearcut | — | — | 5,820 | 92 | 760 |
| Diameter-limit | — | — | 5,850 | 88 | 490 |
| Extensive selection cut | — | — | 9,690 | 100 | 500 |
| Intensive selection cut | — | — | 8,330 | 98 | 330 |
| Check plot | 0 | 124.1 | 880[c] | 48 | 410 |

[a]In trees over 5.0 inches dbh includes live culls.
[b]Percentage of milacres stocked with at least one stem.
[c]No natural openings in this small plot.

No conclusive relationships were apparent between site quality and abundance or distribution of reproduction.

## What Are Some Observed Effects of Other Variables on Reproduction?

### Size of Opening

The effects of size of opening on reproduction have been reported by Smith *(1963)*, Minckler and Woerheide *(1965)*, and Sander and Clark *(1971)*. Trimble and Tryon *(1969)* reported on a study made on the Fernow Experimental Forest.

The objectives of these studies varied somewhat in detail; but in general, they were aimed at determining the relationship of size of opening and height of border trees to the abundance and height growth of reproduction, giving special attention to intolerant species.

Smith *(1963)* studied the height growth of 3-year-old yellow-poplar seedlings in openings in a hardwood stand on a high-quality site in Tennessee. Growth in portions of openings 1/10 acre, ¼ acre, and ½ acre in size was reported. In the two smallest plots, the seedlings were tallest in the center; and height decreased toward the edge of the opening, showing a definite edge effect. In the ½-acre plot, the height was poorest at the border, showing a definite edge effect. Also height growth was somewhat reduced at the center.

Minckler and Woerheide *(1965)* reported on growth of naturally established hardwoods in openings having diameters of ¼, ½, ¾, 1, 1½, and 2 times the height of surrounding trees. Fewer tall stems occurred in the two smallest openings than in the larger ones, and no difference was evident in height growth in openings larger than the ¾ size opening. Also, trees in the central and northern portions were taller than in the rest of the opening.

Sander and Clark *(1971)*, studying openings from ⅛ acre to 5 acres in size in Ohio, found that after 2 years all had enough stems of timber species to form well-stocked stands.

Tryon and Trimble *(1969)*, working in middle-aged hardwood stands, found that the surrounding stand had little or no effect on height growth of reproduction in openings until the plots were as small as ¼ acre. In plots larger than ¼ acre, the border zone of shorter trees was confined largely to the area under the branches of the overstory trees on the edge of the plot. This held true even for intolerant species such as yellow-poplar. The openings had been cut 14 years when the reproduction was measured. The opening dimensions were measured from the trunks—not the crowns—of border trees.

It would seem that where a good species mix at stand maturity is the objective, in-

cluding some desirable intolerants, openings should be at least ½ acre in size and preferably 1 acre.

These suggestions apply to openings that are more or less round; they would not be valid for narrow strips of the same open area.

### Species Composition of the Overstory

The relationship between the species composition of the overstory and the species composition of the reproduction is a tangled skein; but it does seem to be determined in part by some general principles, which operate subject to many modifying influences.

Whether or not a strong relationship exists between the species composition of the old stand and that of the new stand seems to depend largely on whether or not the method of harvest cutting that is used to establish the new stand was the method used to establish the overstory. Following selection cutting with selection cutting can be expected to reproduce a new species mix that is essentially similar to the old stand. Following clearcutting with clearcutting can be expected to do the same thing. However, following clearcutting with selection cutting and following selection cutting with clearcutting can be expected to produce stands composed of species mixes that differ considerably from the old overstories.

Although we cannot substantiate all of the above relationships with Fernow data, we do have considerable information bearing on two of the situations: following clearcutting with selection cutting, and following clearcutting with clearcutting.

In the first instance, selection cutting in areas previously clearcut and occupied by sawtimber stands composed in large part of intolerants is, without exception, reproducing new stands composed almost entirely of tolerants. This is true on both good and better sites *(Trimble 1965)* and on fair sites.

On nine even-aged compartments (covering a site range from 60 to 80 oak site index) that were clearcut, we compared species composition of the 7-year reproduction to the species composition of the old stand *(Trimble 1972)*. With some exceptions, the predominant reproduction was correlated to the most numerous species in the old stand, although the numerical order was somewhat different.

An outstanding exception concerns red oak on excellent sites. Red oak was one of the most numerous sawtimber-size trees in the old stand, but constituted only a very small proportion of the reproduction. Several species were more prominent in the new stand than in the old. These were sweet birch, sassafras, hophornbeam, black locust, and yellow-poplar. With the exception of yellow-poplar, these species are relatively short-lived, and most of them can be expected to drop out before rotation age. Although they occurred infrequently in the old stand when it was cut, these same short-lived species may have been numerous when the stand was 7 years old.

We feel that leaving seed trees has little effect on either the abundance or species composition of the new even-aged stand. Many of the stems present in the new stand are advance reproduction under the old stand. Many new stems are stump sprouts. No doubt many new seedlings come from dormant seed in the duff (yellow-poplar—*Sander and Clark 1971;* black cherry—*Wendel 1972;* white ash—*Clark 1962, Leak 1963)*, and many result from the current year's seed crop at the time the stands are harvested.

### Season of Cutting

Investigating and reporting the effects of season of logging on the establishment and growth of reproduction has been limited largely to one species—yellow-poplar. From a study made on the Fernow Experimental Forest, Trimble and Tryon *(1969)* concluded:

> The results of this study indicate that survival and height growth of yellow-poplar seedlings, in competition with other vegetation that develops simultaneously in newly clearcut areas, are dependent on time of germination. A high proportion of those seedlings that appeared before mid-June competed well with the flush of new vegetation. Most seedlings that came up after 1 July lost out in the race for growing space.

The practical implication of these findings is that the old stand should be logged between the end of the growing season (preferably after yellow-poplar seeds ripen) and 1 May of the following year to favor yellow-poplar reproduction. This would promote maximum

germination and some development of yellow-poplar seedlings early in the growing season before strong competition from other plants develops. Logging in the spring and early summer results in late summer seedlings, which do not survive well; and competing vegetation is able to get a head start on seedlings originating the following year.

This restriction on time of logging becomes less important in areas where the yellow-poplar seed source is extremely plentiful and where site conditions are ideal for this species. However, where the situation is not so favorable for yellow-poplar, control of time of logging might provide the needed advantage.

Sander and Clark *(1971)* came to about the same conclusions from yellow-poplar reproduction studies made in the Central States.

Considering the differences among forest species in seeding characteristics and early development, it is likely that future studies will turn up important effects of season of logging on reproduction establishment for other species.

### Density of Low Vegetation

The effect of competition from low vegetation on tree reproduction has not been measured on the Fernow Experimental Forest; but, based on observations, some generalizations are possible.

Several charactertistic types of shrubby and herbaceous cover hinder the establishment and development of reproduction under both selection cutting and clearcutting. On good and better sites, the tolerant, long-lived rhododendron growing in dense thickets hinders the establishment of seedling reproduction unless its density is reduced through cutting or chemical treatment. It resprouts after cutting; but regrowth is so slow that seedlings can get started and grow beyond its shade, at least after clearcutting. Mountain laurel, found on the poorer sites, has somewhat the same effect as rhododendron; but it is less abundant. In moist swales under sawtimber stands on high quality sites, a dense cover of such herbaceous growth as nettles, touch-me-not, and black snakeroot often carpets the ground. This heavy herbaceous layer apparently retards the early development of reproduction—especially such intolerants as yellow-poplar. In the situations where it is profuse, this type of cover seems to persist indefinitely after selection cutting and for a number of years after clearcutting.

Tyron and Carvell *(personal communication March 1973)* have noted that in some areas of the central Appalachians, patches of fern growing under tree canopies apparently prevents the establishment of even the most tolerant reproduction.

After clearcutting, but not selection cutting, a heavy cover of blackberry plants develops on all sites. Although seedlings do come through this blanket, it is our opinion that it delays their height growth from the second to about the fifth year and that its shade discriminates against the intolerant species. Moreover, because of its persistent foliage and weak stem, it flattens out under snowfall, which bends over, breaks, and deforms many seedlings in the process.

### Grapevines

Wild grapevines are a threat to young hardwood stands after clearcutting on good and excellent sites in many areas of the central Appalachians. They are also a threat following any type of partial cutting, such as group selection, that creates large holes in the canopy. Because this long-lived vigorous vine is fairly shade intolerant, it does not pose as serious a threat under an individual tree selection system. In selection cutting, it can be controlled by severing the stems. Results of studies currently under way on the Fernow Experimental Forest indicate that this vine does not occur frequently on fair and poorer sites.

Grapevines reproduce by seed and by sprouting. Seeds can lie dormant many years in the forest floor and then germinate. It is the sprouts that are the real problem. Sprouts from grapevine stumps cut off at the time of clearcut harvest grow 5 to 15 feet the first year, mounting quickly into any young tree in the vicinity.

Grapevines damage young trees by breaking limbs and tops, twisting and bending over the main stem, augmenting ice and snow damage, and submerging the tree foliage in

large grape leaves, thus interfering with photosynthesis. In some young even-aged hardwood stands, grapevines are adversely affecting a majority of the stems in the stand.

Satisfactory measures for controlling grapevines have not as yet been worked out for even-aged systems, but several studies are under way.

### Susceptibility to Spring Frosts

Differences in susceptibility among species to damage by spring frosts may have an effect on species composition of stands in certain areas. This phenomenon has been investigated and reported on by Tryon and True *(1964)*. Some of their work was done on the Fernow Experimental Forest. With permission, their publication is quoted in the following:

> Frosts occur frequently in the Appalachian region, and spring frosts which occur after growth has started are especially damaging to forest trees. Such frosts deform stems, reduce growth rate, and may kill the smaller reproduction. Although frost injury is widespread and recurs each year, the damage is often unnoticed or is observed months later without its true cause being recognized.
>
> The Appalachian region's irregular topography provides many pockets for the accumulation of cold, heavy air. Such conditions are ideal for heavy spring frosts. Many of the susceptible species . . . or . . . such as yellow-poplar, frequent rich cove and bottomland soils where these frosts are common, severe, and very damaging.
>
> Trees of all sizes may be damaged, but the reproduction and saplings are usually most severely injured. The period of establishment is therefore critical.

The investigators prepared a frost-susceptibility rating tabulation based on frost damage during the springs of 1961 and 1963. They examined tree species in 12 localities in northern and east-central West Virginia and rated the degree of damage by late frosts to the newly formed leaves and shoots:

| *Highly susceptible*[a] | *Moderately susceptible* | *Less susceptible* | *Least susceptible* |
|---|---|---|---|
| Sassafras | Fraser magnolia | Smooth alder | Slippery elm[b] |
| American sycamore | White ash[c] | Serviceberry | Willow[b] |
| Black locust | American chestnut | Witch-hazel | Flowering dogwood[b] |
| American beech | White oak | Striped maple | Hawthorn |
| Cucumbertree | Scarlet oak | Fire cherry | American basswood |
| Yellow-poplar | Chestnut oak | Red maple | Sugar maple |
| Hickory spp. | Northern red oak | | Black cherry |
| Black walnut | Yellow birch[c] | | |
| Butternut[a] | Black birch[b] | | |

[a]The most susceptible species are at the top, and the least susceptible are at the bottom within each susceptibility class.
[b]Based on few observations.
[c]Considerable variation in degree of damage.

Again quoting Tryon and True:

> It is evident that considerable variation exists in susceptibility to late frosts among these hardwoods, including the more valuable species. Within the limits of the study, black cherry was definitely most resistant to late frost damage, and was followed by sugar maple and American basswood which were slightly less resistant. Yellow-poplar, black walnut, and American beech were among the species most susceptible to frost damage, with the oaks being slightly less susceptible. Considerable tree-to-tree variation in frost susceptibility was found for white ash and yellow birch.

The investigators recommend that when stands are being regenerated in locations where frost pockets occur, resistant species should be favored. They recommend also that, in such areas, regeneration by sprouts be discouraged because their observations indicated that young sprouts are more heavily damaged by frosts than are seedlings.

## SUMMARY AND DISCUSSION

Reproduction trends were related in this report primarily to site quality and to type of timber harvest—selection cutting versus clearcutting. But other factors affect reproduction, and some of these were discussed.

In general, advance reproduction composed mostly of the more tolerant species exists in fair numbers and is fairly well distributed un-

der unmanaged sawtimber stands. Composition varies some with site quality, but on excellent, good, and fair sites, sugar maple, red maple, and beech are predominant, with oak often numerous on the fair sites.

Reproduction has been found satisfactory in numbers and distribution after both clearcutting and individual tree selection cutting, but the species composition differs greatly; tolerants predominate following selection cutting but generally a good representation of intolerants, as well as tolerants, can be expected after clearcutting—depending somewhat on the density of advance reproduction and the abundance of stump sprouts.

Site quality makes a difference in the species composition of reproduction after cutting, and the difference is greater for clearcutting than for selection cutting. After clearcutting on the excellent sites, we can expect a good representation of yellow-poplar and black cherry; and on the fair sites, we can expect a variable number of oak stems. After selection cutting, we get beech and sweet birch on both sites with sugar maple in the number one spot on the excellent site and red maple better represented on the fair site.

When group selection or patch cutting is the reproduction method and where the objective is a good species mix, including some intolerants, results of research suggest that openings should be at least ½ acre in size and preferably 1 acre.

A relationship usually exists between the species composition of the old stand and the reproduction where the cutting method is the same one as used in establishing the overstory. For example, stands established by clearcutting when clearcut again reproduce more or less the same species. However, when selection cutting follows clearcutting, a drastic change may take place in species composition; and such species as red oak, yellow-poplar, and black cherry may be replaced by the maples and beech.

Season of logging has some effect on the germination and development of yellow-poplar reproduction. There may be some advantage to logging between about 1 September and 1 May to favor this species.

Several characteristic types of low vegetation, such as rhododendron and blackberry thickets, retard the development of reproduction.

Wild grapevines pose a threat to young even-aged hardwood stands on the better sites. Following individual tree selection cutting and on sites of low quality, this vine is less of a problem.

What do the results of these reproduction studies mean in terms of forest practices? Do they indicate that we know enough to tailor our cutting methods by site class to get specific stand composition?

Within limits and subject to certain qualifications, we can predict and influence stand composition in most situations in the Central Appalachians. If we practice individual tree selection cutting on our better sites, we can expect to get stands composed largely of maples and beech. The two highly valued trees, yellow-poplar and black cherry, will be scarce indeed; a loss of timber value, esthetic qualities, and—in black cherry—a heavy blow to game. If we practice even-aged silviculture with clearcutting harvests, we will reproduce these two species and a great number of other species also, including the maples and beech. We will, in effect, retain the same kinds of forests on our high-site areas that are so universally admired today by sightseers and hunters.

Our oak stands on the lower quality sites are today also typically even-aged. These oak stands are not only valuable for wood products, but they are essential to such game species as squirrels and turkey. Under individual selection cutting, they will be succeeded by the more tolerant species such as red maple, beech, black gum, and sweet birch. The oaks are intermediate to intolerant; and although they will germinate and grow for a while in shade, they need canopy removal to develop.

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# APPENDIX

Common and scientific names of species referred to in this study:

| | |
|---|---|
| **TREES** | |
| Alder, smooth | *Alnus serrulata* (Ait. Willd.) |
| Ash, white | *Fraxinus americana* L. |
| Aspen, bigtooth | *Populus grandidentata* Michx. |
| Basswood | *Tilia americana* L. |
| Beech, American | *Fagus grandifolia* Ehrh. |
| Birch, yellow | *Betula alleghaniensis* Britton |
| Birch, sweet (black) | *Betula lenta* L. |
| Butternut | *Juglans cinerea* L. |
| Chestnut, American | *Castanea dentata* (Marsh.) Borkh. |
| Cherry, black | *Prunus serotina* Ehrh. |
| Cherry, pin (fire) | *Prunus pensylvanica* L. f. |
| Cucumbertree | *Magnolia acuminata* L. |
| Dogwood, flowering | *Cornus florida* L. |
| Elm, slippery | *Ulmus rubra* Muhl. |
| Gum, black | *Nyssa sylvatica* Marsh. |
| Hickory | *Carya* spp. |
| Hophornbeam, eastern | *Ostrya virginiana* (Mill.) K. Koch |
| Locust, black | *Robinia pseudoacacia* L. |
| Magnolia, Fraser | *Magnolia fraseri* Walt. |
| Maple, red | *Acer rubrum* L. |
| Maple, striped | *Acer pensylvanicum* L. |
| Maple, sugar | *Acer saccharum* Marsh. |
| Oak, black | *Quercus velutina* Lam. |
| Oak, chestnut | *Quercus prinus* L. |
| Oak, northern red | *Quercus rubra* L. |
| Oak, scarlet | *Quercus coccinea* Muenchh. |
| Oak, white | *Quercus alba* L. |
| Rhododendron | *Rhododendron maximum* L. |
| Sassafras | *Sassafras albidum* (Nutt.) Nees. |
| Serviceberry, downy | *Amelanchier arborea* (Michx. f.) Fern. |
| Sourwood | *Oxydendrum arboreum* (L.) DC |
| Sycamore, American | *Platanus occidentalis* L. |
| Yellow-poplar | *Liriodendron tulipifera* L. |
| Walnut, black | *Juglans nigra* L. |
| Willow | *Salix* spp. |
| **SHRUBS AND VINES** | |
| Blackberry | *Rubus* spp. |
| Black snakeroot | *Cimicifuga racemose* (L.) Nutt. |
| Grapevine | *Vitis* spp. |
| Hawthorn | *Crataegus* spp. |
| Mountain laurel | *Kalmia latifolia* L. |
| Nettles | *Laportea canadensis* (L.) Wedd. |
| Touch-me-not | *Impatiens* spp. |
| Witch hazel | *Hamamelis virginia* L. |

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# Formulation and Application of Methoxychlor for Elm Bark Beetle Control

by R. A. Cuthbert
J. H. Barger
A. C. Lincoln
and P. A. Reed

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NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

ROY A. CUTHBERT received a B.S. degree in botany and a M.S. degree in plant physiology from the Ohio State University. He has worked on insect-vectored diseases of forest trees at the Northeastern Forest Experiment Station at the Insect and Disease Laboratory in Delaware, Ohio since 1966.

JACK H. BARGER received his B.S. degree in education from Concord College and his M.S. and Ph.D. degrees in entomology from the Ohio State University. In 1965 he joined the Northeastern Forest Experiment Station at the Insect and Disease Laboratory in in Delaware, Ohio and works on insect-vectored diseases of forest trees.

A. CHARLES LINCOLN received his B.S. degree in forestry from the University of Massachusetts and his M.S. and Ph.D. degrees in entomology from the State College of Forestry at Syracuse University. He joined the Forest Service in 1962 and served as leader of the shade tree insect project in Delaware, Ohio from 1968 to 1972. Since 1972 he has been Chief of the Pesticide Branch of the Environmental Protection Agency in Chicago, Illinois.

PHYLLIS A. REED attended the Ohio State University and was a laboratory technician at the Forest Insect and Disease Laboratory in Delaware, Ohio from 1965 to 1972. She is now pesticide inspector for the Environmental Protection Agency in East Lansing, Michigan.

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# Formulation and Application of Methoxychlor for Elm Bark Beetle Control

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## ABSTRACT

American elm trees, *Ulmus americana* L., were sprayed with different formulations of methoxychlor by mistblower, hydraulic sprayer or helicopter. Twig-crotches were collected from sprayed trees for GLC assay and *Scolytus multistriatus* (Marsham) bioassay. Hydraulic deposits were heaviest but the mistblower was more efficient in terms of amount deposited per pound of methoxychlor sprayed. Helicopter deposits were light on lower branches but were comparable to mistblower and hydraulic deposits in tops of trees, where protection is needed most.

Federal laws regulating use of DDT have forced arborists and city foresters to seek other materials to protect elms from smaller European elm bark beetles, *Scolytus multistriatus* (Marsham), principal vectors of Dutch elm disease fungus. Methoxychlor was shown to be effective and has been approved for this purpose. However, arborists need more information on the effectiveness of methoxychlor formulations when applied by mistblower, hydraulic sprayer, or helicopter. In studies of DDT formulations (Whitten 1945, Matthysse et al. 1954), it was suggested that white oil might increase insecticide deposits on tree tops and Whitten reported that quick-breaking emulsions may be preferable to more stable ones, but quantitative data were not given. Although formulations with HAN solvents damage paint finishes less than xylene, and formulations containing 32% methoxychlor cost less to ship and handle, the effectiveness of these formulations has not been adequately tested. Therefore, in 1970 the Forest Service conducted an experiment in cooperation with state, city and private organizations to compare the amounts of methoxychlor deposited on elm twigs by spraying with different formulations and types of equipment.

## METHODS AND PROCEDURES

### Location and Treatments

The experiment was conducted in Ohio and Massachusetts. All trees in Ohio and about half of those in Massachusetts had been sprayed previously with DDT but none had been sprayed with methoxychlor for at least 4 years. Ohio trees ranged in height from 31 to 69 ft. (average 51 ft.); Massachusetts trees ranged from 30 to 90 ft. (average 64 ft.), and, in general, had fewer branches in the lower part of the crowns.

A John Bean Rotomist[1] 100-G mistblower with No. 5 discs/5 hole whirlplates calibrated at 2 gal. per minute was used in Ohio and a Hardie Aero-Mist L-80-A mistblower with 2 tangential type T No. 1120M nozzles calibrated at 1.5 gal. per minute was used in Massachusetts.

John Bean Royal hydraulic sprayers were used in both areas. All formulations in Ohio were applied at about 25 gal. per minute with a No. 16 disc. In Massachusetts, formulations 2 and 4 were applied at 29 gal. per minute with a standard Bean shade tree gun and formulations 1, 3, and 5 were applied at 23 gal. per minute with a No. 10 disc (table 1).

In Ohio, the helicopter sprayed from 15 to 25 ft. above trees with 20 D6 nozzles on a 32 ft. boom at 45 psi. In Massachusetts, the helicopter sprayed from 10 to 20 ft. above trees at 0 to 5 mph with a total of 27 D8 nozzles with No. 45 cores on 2 lateral 10 ft. booms and 1 aft 8 ft. boom at 45 psi. boom pressure. Methoxychlor concentration in spray solutions was 2 percent for hydraulic and 12.5 percent for mistblower. In Massachusetts, formulations 1 and 2 were applied by helicopter at 12.5 percent but 3, 4, and 5 were applied at 8 percent due to errors in mixing. All formulations applied by helicopter in Ohio were at 12.5 percent. The amount of methoxychlor sprayed at a tree was estimated by either timing or metering

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Table 1.—*Formulation specificatons of methoxychlor sprayed in Ohio and Massachusetts, Spring 1970*

| Formulation no. | Type of solvent | Type of emulsifier | Percent methoxychlor | Additives |
|---|---|---|---|---|
| 1 | Xylenes[a] | Q.B.[b] | 25 | — |
| 2 | Xylenes | S.B.[b] | 25 | — |
| 3 | Xylenes | Q.B. | 32 | — |
| 4 | Xylenes | Q.B. | 25 | 8% white oil |
| 5 | Heavy aromatic naphthalenes (HAN) | Q.B. | 25 | — |

[a]Boiling range 270-310° F.; KB 96.
[b]Q.B. separation <10 min; S.B. >10 min.

the spray application. Trees were sprayed from 18 to 30 April 1970.

### Design and Sampling

The experimental design is a repeated measure two-factor design replicated at two locations. The 14 treatments were randomly assigned to 14 plots in each location, with each plot containing five trees. Test variables were methoxychlor deposits and bark beetle responses on twigs from 12 sectors of each tree. The crowns of trees were marked off into 12 sectors (three levels and four quadrants). Five twigs were collected from each sector for chemical analysis. An additional sample of 10 twigs per sector was collected for bioassay from 26 trees which had not been previously sprayed with DDT. Trees were sampled twice, once from 6 to 21 days after spraying and again from 152 to 172 days after spraying.

### Chemical Assay

Samples were analyzed on a Varian Aerograph[1] chromatograph equipped with an Ni-63 electron capture detector. A ⅛-in. O.D. glass column, 6 ft. long, packed with 5 percent DC-11 on 70 to 80 mesh Aeropack 30 with a nitrogen exit flow of 30 to 35 ml./min. was used. Relevant temperatures were: injection port 245°C., column 235°C., detector 375°C. Retention time of methoxychlor was about 4 minutes.

Circular patches (4.5 $mm^2$.) were cut from crotches of twigs with sharpened tubing. Methoxychlor was dissolved from five patches of a sector by shaking them in a nanograde hexane for about 15 minutes. When necessary, samples were diluted with up to 110 ml. of hexane to bring the amount of methoxychlor injected within linear range of the detector. Three $\mu$l. of hexane-methoxychlor extract were injected into the chromatograph. After every fourth sample, methoxychlor standards were injected. The heights of sample peaks were compared with standard peaks to determine the methoxychlor concentration in samples.

Most methoxychlor deposits on elm twigs ranged from 0.1 to 1.0 $\mu g./mm^2$. (ca. 200 to 2,000 ppm). Because this concentration is high, a complex sample preparation procedure was not necessary. The procedure was sufficient to distinguish biologically significant differences in amounts of methoxychlor. However, the assay overestimated light deposits and underestimated heavy deposits. Calibration studies show that recovery of methoxychlor added to twigs was about 133 percent at 0.10 $\mu g./mm.^2$, 80 percent at 0.75 $\mu g./mm.^2$, and 75 percent at 100 $\mu g./mm.^2$.

### Bioassay

A bioassay described by Barger et al. (1970) was used to evaluate feeding rates of beetles. A beetle was caged in a small perforated brass cylinder on the crotch of an elm twig and allowed to feed for 24 hours. A twig was considered protected if a beetle did not feed to the xylem.

### Analysis

For each treatment (combination of formulation, equipment, location), means of methoxychlor deposits were plotted against variances. There was a consistent relationship

between $\overline{X}$ and $S^2$ for treatments applied by the same equipment. Because of this relationship, observations of methoxychlor deposits were transformed to logarithm Y to stabilize variances for ANOVA. In addition, the relationship for hydraulic treatments was different from treatments by mistblower and helicopter. Therefore, data from helicopter and mistblower treatments were analyzed together and a separate analysis was run for the treatment with hydraulic spraying.

The association between chemical assays and bioassays was approximated graphically. Since the two assays cannot be conducted on the same twigs, amounts of methoxychlor on bioassayed twigs were estimated by the mean methoxychlor residue on the other random sample of twigs from the same sectors. Beetle feeding failure on twigs within a range of estimated amounts of methoxychlor were averaged and plotted at the midpoint of this range.

Because negligible spray deposits resulted from helicopter treatments in Ohio, none of the data from these trees were analyzed. Because most trees in Massachusetts had too few twigs in the lower sections, only data from the top and middle levels of these trees were included in the analysis.

## RESULTS AND DISCUSSION

Important parameters of spray application are: amount and variation in deposits; persistance of deposits; and ability of insecticide to prevent feeding. Insecticides should be highly toxic to beetles and should be deposited where beetles are likely to contact them. There should be uniform coverage, each twig with just enough insecticide to deter feeding. Toxic residues should remain on twigs for several months.

Analysis showed that the significant factors in the experiment were type of spray equipment and level in tree.

### Amounts and Variation in Deposits

Amounts of methoxychlor deposited differed with the method of application. The difference was most evident at the middle and lower levels of tree crowns. Deposits on middle and lower levels of trees sprayed by mistblower or hydraulic sprayer were about twice as heavy as deposits on top (table 2).

Helicopter deposits, however, were more than twice as heavy on top as on the middle. On treetops, which are considered most susceptible to beetle attack (Wolfenbarger and Buchanan 1939), the three types of equipment resulted in about equally heavy deposits with the doses used in this study.

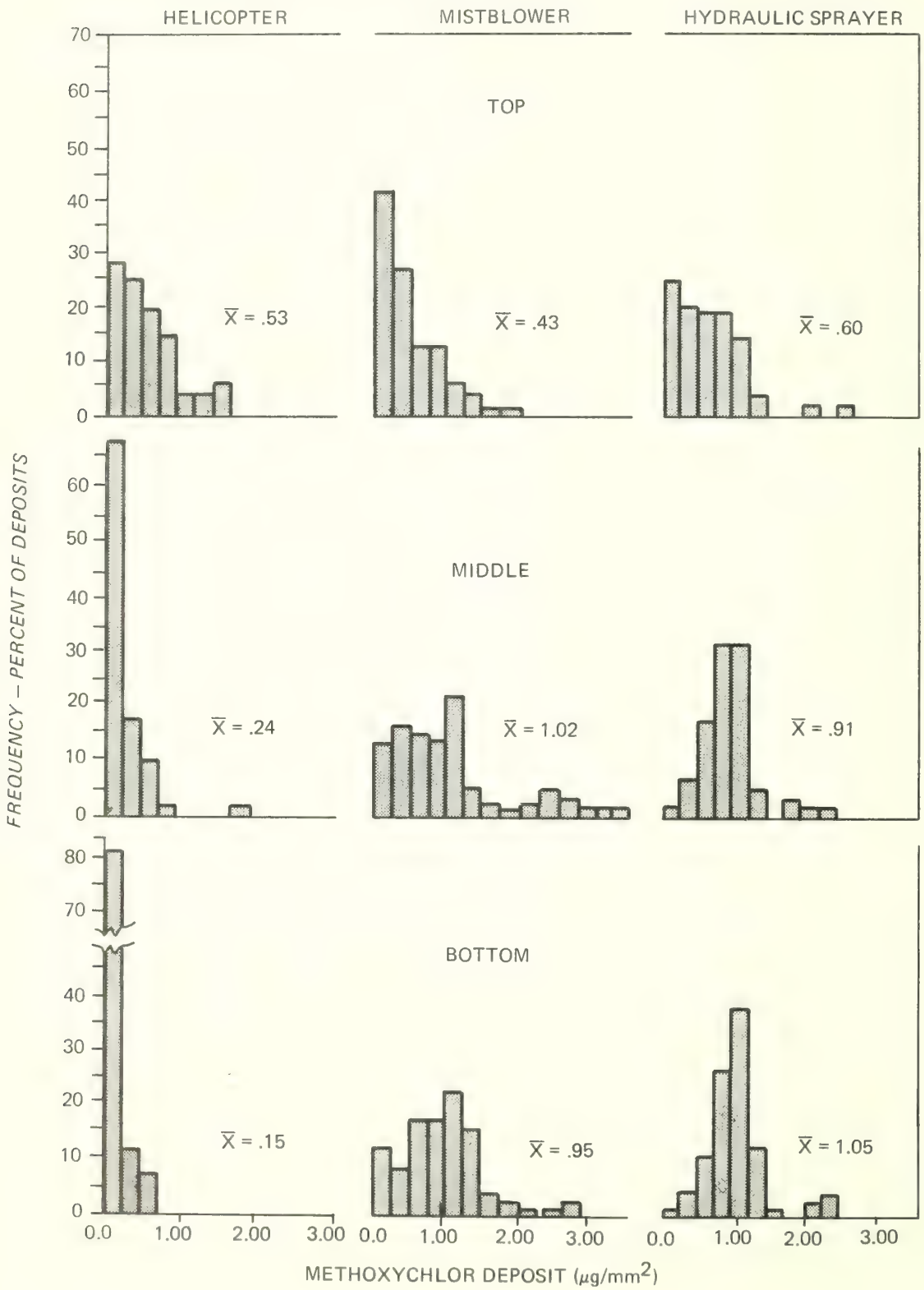
The different types of spray equipment required the application of different doses to the trees. The average dose per tree was 4.2 lb. for the hydraulic sprayer, 1.9 lb. for the mistblower, and 1.6 lb. for the helicopter even though the average tree heights were about the same: 52 ft., 57 ft., and 50 ft., respectively. Comparing the amount of methoxychlor de-

Table 2.—*Average methoxychlor deposits detected on elm twig crotches after spraying with mistblower, hydraulic sprayer or helicopter*

| Type of equipment | Average $\mu$g methoxychlor/mm.$^2$ of bark | | | | | |
|---|---|---|---|---|---|---|
| | Initial samples from | | | Final samples from | | |
| | Top | Middle | Bottom[a] | Top | Middle | Bottom[a] |
| Mist | 0.43 | 1.02 | 0.95 | 0.16 | 0.45 | 0.54 |
| Hydraulic | .60 | .91 | 1.05 | .21 | .44 | .57 |
| Helicopter | .53 | .24 | .15 | .14 | .10 | .06 |
| Mist versus helicopter | NS | ** | — | — | — | — |

NS - Not significant at .05 level of probability.
** - Significant at .01 level of probability.
— - No test completed.
[a]Values on bottom levels not included in averages or statistical analyses because many trees had few twigs on bottom levels.

Figure 1. — Frequency distribution of initial methoxychlor deposits on three levels of elm crowns, sprayed by helicopter, mistblower, and hydraulic sprayer.



posited on a tree with the amount sprayed at a tree, the mistblower is clearly the most efficient. Comparing the amount deposited on treetops with the amount sprayed, the helicopter is the most efficient.

Although spray operators were skilled and worked carefully, uneven coverage was common with each type of equipment. Methoxychlor deposits varied widely among tree sectors. Often there was a 10X difference between the lightest and heaviest deposits within the crown of a single tree and a 2X difference between the lightest and heaviest deposits on trees sprayed at the same time by the same operator, with the same equipment and formulation. Only a small part of deposit variability can be explained by differences in tree size. Doses depended on tree size; an operator sprayed a tree until he estimated it was adequately covered. Amounts of methoxychlor sprayed at trees varied from 1.1 to 11.2 lb., depending on tree size, equipment, and operator.

The frequency distribution shows the variation in deposits for each type of equipment on each level of the trees (fig. 1). The best distribution of deposits was on the bottom level of hydraulically sprayed trees. Most twigs on this level were consistently covered with relatively heavy amounts of methoxychlor. Seventy-six percent of the twigs had between 0.75 and 1.50 $\mu$g./mm.$^2$ of methoxychlor.

A comparison between deposits at the middle level by mistblower and by hydraulic spraying shows that variances differed although average deposits on trees sprayed by both types of equipment were about the same, 1.02 and 0.91 $\mu$g/mm.$^2$ On mistblower-sprayed trees about 3X as many twigs were covered with less than 0.25 $\mu$g./mm.$^2$ as on hydraulically sprayed trees.

The variability of deposits on treetops was similar for each type of equipment. Hydraulic and helicopter deposits were slightly heavier than mistblower deposits. However, for all 3 types of equipment at least 25 percent of the twigs had deposits of less than 0.25 $\mu$g./mm.$^2$

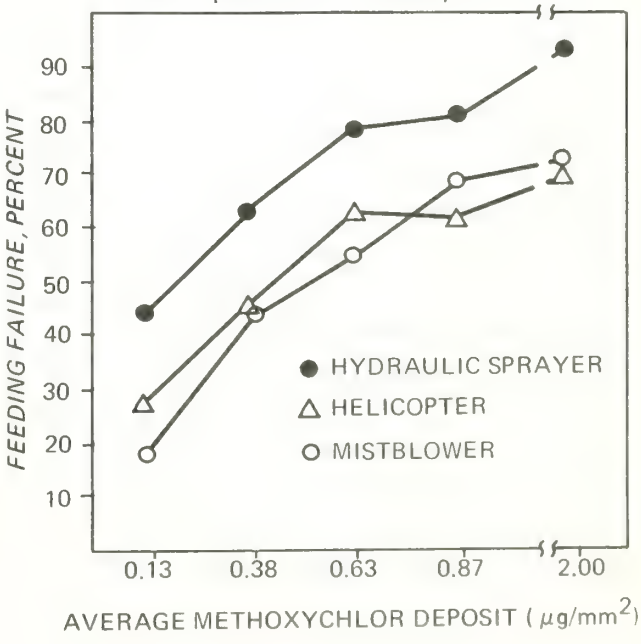
## Persistence

In general, methoxychlor deposits from all formulas sprayed by each type of equipment in both areas weathered at the same rate (table 2). Deposits after 5 months depended primarily on initial deposits. After 5 months, residual methoxychlor was from one-third to one-half the initial amount.

## Feeding Prevention

Beetle feeding was inversely proportional to amounts of methoxychlor on twigs. In a study of methoxychlor effectiveness (Barger et al. 1972), about 90 percent of elm bark beetles were deterred from feeding by 1.1 $\mu$g./mm.$^2$ of methoxychlor. About 50 percent were deterred by 0.5 $\mu$g./mm.$^2$ Toxicity of deposits by mistblower and helicopter were similar in this study (fig. 2). However, deposits from hydraulic sprayers appeared to be 1.5 times as toxic. One possible explanation for the greater toxicity of hydraulic-sprayer deposits is uniform coverage. All twigs within a sector were covered with about the same amount of insecticide. On the other hand, mistblowers and helicopters atomize spray, and methoxychlor deposits vary among twigs. Some twigs may have heavy de-

Figure 2. — Association between beetle feeding and methoxychlor deposits from mistblower, helicopter, and hydraulic applications. Average bark beetle feeding failure rate within intervals of estimated methoxychlor deposits (plotted at the midpoint of the intervals).



posits and others light deposits, and beetles may feed on the lightly covered twigs.

The best equipment for spraying elms depends on job requirements. Helicopter applications offer treetop coverage equal to that achieved by ground equipment, but at lower doses and with greater speed. However, helicopters are so sensitive to wind that in some areas few days are suitable for spraying.

Hydraulic sprayers have the advantages that deposits are heavier and more uniform than with other equipment; they are maneuverable; and they are least sensitive to wind. However, hydraulic sprayers use more than twice as much insecticide as helicopters and require more time.

Mistblowers are intermediate. Their speed, maneuverability, sensitivity to wind, amount of insecticide used, and amount deposited are between those of hydraulic and helicopter applications.

## SUMMARY AND CONCLUSION

When used as recommended, the three types of spray equipment produced considerably different deposits. Deposits from the hydraulic sprayer were heaviest and most uniform, but it used twice as much insecticide as the mistblower or helicopter. Average deposits applied by mistblower were almost as heavy as those of the hydraulic sprayer, but deposits were more variable. Although average deposits from helicopter spraying were about half as heavy as those from the mistblower or hydraulic sprayer, deposits on treetops were about the same for all three types of equipment. Most methoxychlor applied by helicopter was on treetops, whereas most applied by mistblower or hydraulic sprayer was on the lower crown. Regardless of the equipment, most treetop deposits were less than 0.5 $\mu$g./mm.$^2$ Protection should be best on the tops of trees because beetles feed more there than at lower levels.

The five formulations resulted in about the same deposits. If real differences existed among formulations these differences were small compared to differences among plots and trees.

Because weathering reduced methoxychlor deposits to one-third to one-half initial amounts, protection appears to be marginal after 5 months.

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# QUALITY DISTRIBUTION OF PALLET PARTS FROM LOW-GRADE LUMBER

by

**Hollis R. Large & Richard E. Frost**

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NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

HOLLIS R. LARGE received his bachelor of science degree in forestry from the University of Tennessee in 1969 and his master's degree from the same institution in 1971. He joined the staff of the USDA Forest Service's Northeastern Forest Experiment Station at the Forest Products Marketing Laboratory, Princeton, West Virginia, in 1971.

RICHARD E. FROST received a bachelor of science degree in wood technology from the University of Massachusetts in 1967. During the summer of 1966 he was a management trainee with U. S. Plywood Corporation. He joined the Forest Products Marketing Laboratory, U. S. Forest Service in June 1967. He has been employed as a research scientist and research technologist collecting and evaluating data for the research on unitization of industrial and commercial commodities on wooden pallets.

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# QUALITY DISTRIBUTION OF PALLET PARTS FROM LOW-GRADE LUMBER


## ABSTRACT

To produce better pallets, the higher quality parts should be used in the more vulnerable positions in the pallet. To determine the feasibility of doing this, pallet parts cut from commonly used lumber mixes were graded into four quality levels. The distributions obtained indicate that sufficient numbers of high-quality parts can be cut from existing raw material to allow selective placement. Four species groups —eastern hardwood, southern pine, Douglas-fir, and a small amount of western hardwood—were included in the study.


The most efficient way to produce better pallets is to place higher quality parts in critical places in the pallet. The "PEP" study on the performance of wooden pallets under normal use conditions has shown that the more exposed pallet parts are subject to more damage than interior parts.[1] The selective placement of high-quality parts in the pallet structure reduces damage and extends the useful life of a pallet. To employ our wood resources efficiently and to minimize the cost of the wooden pallet, pallets must be constructed so as to get the maximum benefit from the raw materials available.

The primary objective of this study was to determine if the mix of lumber presently used to manufacture pallet parts is high enough in quality to provide the quality parts needed in the exposed locations of pallets.

The vulnerable areas of the pallet referred to here include:

(a) the two top deck endboards—15 percent of the total deck volume;

(b) the two bottom deck endboards—15 percent of the total deck volume; and

(c) the two outside stringers—67 percent of the total stringer volume.

A secondary objective was to evaluate the effect of species and cutting method on the quality distribution of parts cut from commonly used lumber grades.

## BACKGROUND

Before World War II there was a very limited market for the low-grade lumber cut in and around the pith area of logs, and this waste material created disposal problems in many sawmills. The handling of unit loads of products with forklift trucks and wooden pal-

[1] Wallin, W. B., J. J. Strobel, R. E. Frost, and P. R. Stinson, PEP Research Study Report. Unpublished. Northeastern Forest Experiment Station, Forest Products Marketing Laboratory, Princeton, West Virginia 482 pp.

lets developed during World War II. The adoption of this method by industry has provided large and stable market outlets for the low-grade lumber used to manufacture wooden pallets. The wooden pallet and container industry now uses nearly one-fourth of all hardwood lumber produced in the United States. Increased handling costs have encouraged unit-load movement of goods and in turn increased the demand for pallets.

During the years immediately following World War II, the pallet and container industry was almost perfectly competitive. There were many small firms producing and selling pallets; entry into and exit from the industry was easy because the investment in plant and equipment was very low; and the products of different manufacturers were not differentiated. In an attempt to relieve some of the competitive pressure, many manufacturers took advantage of small "captive" markets whereby they could differentiate their products by producing a pallet for a specific industry need. Pallets were used primarily for handling products in plants, and as a result pallet sizes and designs were specified to fit individual products. Exchange of pallets between different owners did not develop significantly until the middle 1950s.

### Pallet Exchange System

The most efficient application of unit-load handling is the system in which pallets are exchanged freely among the various shippers, carriers, and receivers in different establishments, firms, and industries. Such a system on a national scale reduces the costs of handling and shipping products by using labor and equipment more efficiently, by using pallets more efficiently, and by using raw materials more efficiently to produce pallets. But because different firms and industries use such a wide range of pallet designs and sizes, the implementation of major inter-industry pallet exchange systems is hampered.

Two basic requirements of pallets to be used in exchange sysetms are: (1) standards of quality for all pallets within the system to insure equal exchange; and (2) standards of design and size to insure that all pallets can be used in all materials handling systems and in all transportation equipment.

### Current Practices

Pallet manufacturers use lumber that is "left over" from the manufacture of other primary products. The cost, quality, and species mix of lumber available for pallet manufacture varies with and is dependent upon the markets for such primary products as furniture, general construction, flooring, and cross-ties. Most pallets are manufactured from what is known as "pallet grade" or "sound square edge" lumber and cants. In standard lumber grade terms, pallet grade material is generally composed of varying proportions of No. 3A and 3B Common, and in some instances a small portion of No. 2 Common, lumber. Most pallet producers do not grade the lumber they buy; nor do they grade the pallet parts they produce. Different quality pallets are normally produced by varying the proportions of higher quality lumber used to produce the parts and by setting higher quality levels *for* "culling out" unsuitable parts after manufacture.

Before there can be a quality selection system for pallet parts that will insure the placement of high-quality parts in vulnerable areas of a pallet, quality classes must be defined and their distributions measured. After quality distributions have been determined, the information can then be related to the quality selection system.

This information is of value to pallet producers as a means of evaluating the quality of parts they presently produce or buy, and to pallet users as a means of determining that the pallets actually do meet the specifications.

## METHODS

Four species groups—eastern hardwood, southern pine, Douglas-fir, and western hardwood—all commonly used in the production of pallets, were included in the survey. Pallet deckboards were selected at random from existing inventories at several pallet plants in the eastern, southern, and western United States. Only deckboards were evaluated in this survey because they were available and easily graded. It was assumed that the quality distribution of stringers is approximately the same when they are cut from raw material of similar quality.

Each part was "graded" into one of four grades developed from the pallet specifications of the National Wooden Pallet and Container Association, and used by the Forest Products Marketing Laboratory, United States Forest Service, in the conduct of the "PEP" study. The data obtained on the grade distribution of parts used in the "PEP" pallets is thus comparable to the data obtained from this study.

In general, the four grades were designed to allow the following distinctions:

Grade 2 & Better—approximately one-fourth reduction in strength due to defect.
Grade 3—approximately one-third reduction in strength due to defect.
Grade 4—approximately one-half reduction in strength due to defect.
Grade 5—cull—part with more than 50 percent reduction in strength due to defects.

The grading criteria are presented in detail in the appendix.

# RESULTS

## EASTERN HARDWOOD

### Yields

Data were collected at mills from New York to Alabama to obtain a representative sample of species. Species mixes included maple, beech, and birch from the Northeast; oak from central Appalachia; and a mixture of oak and gum from the Southeast.

At seven different mills a total of 17,817 parts totaling 20,942 board feet were graded (table 1). At three of the seven mills, graded 4/4 lumber samples of approximately 1,000 board feet each of 2 Common, 3A Common, and 3B Common were cut into pallet parts. This provided information on the grade distribution of pallet parts cut from specific lumber grades. The lumber samples were selected in random lengths and widths from existing inventories at the pallet plants or supplier sawmills. The samples at the other four locations were of pallet grade and sound square edge material which was not sorted by standard lumber grades.

Table 1.—Summary of eastern hardwood sample

| Lumber grade | Total no. of parts graded | Total Volume (bd. ft.) | Predominant species |
|---|---|---|---|
| 2 Common | 2,023 | 2,741 | Oak, Maple |
| 3A Common | 1,283 | 1,895 | Oak, Maple |
| 3B Common | 1,697 | 2,599 | Oak, Maple |
| Pallet grade (Northeast) | 7,994 | 9,056 | Maple, Oak, Beech |
| Pallet grade (Southeast) | 4,820 | 4,651 | Oak |
| Total | 17,817 | 20,942 | |

The results indicate that lumber grade and cutting method have a significant effect on the quality distribution of pallet parts. Species of wood did not affect the quality distribution of parts cut from lumber of comparable quality.

Hardwood pallet parts are produced normally by gang cutting, in which several saws cut simultaneously to produce several parts. For processing hardwood lumber into pallet parts a multiple crosscut process is employed to reduce a 10-foot board, for example, into three 40-inch deckboards. In this process, there is no opportunity to cut around defects. This is the process that was used to produce the "gang" cut parts evaluated in this study. Parts are also "gang" cut by cross-cutting cants to length and then processing the cants through a multiple-rip gang saw.

Selective cutting employs a single saw which makes one cut at a time to produce one part at a time. When this method is employed, the defects are usually cut out and several different lengths of parts may be produced from one board.

The gang method is the method most often used to produce hardwood pallet parts. Selective cutting is used mostly by manufacturers who lack the capital required to install gang saws. The selectively cut hardwood parts evaluated in this survey required an average cut-up time of 70 minutes per thousand board feet and yielded 85 percent usable volume. Gang-cut parts required an average cut-up time of only 31 minutes per thousand board feet and yielded 88 percent usable volume.

Gang-cut 3A Common lumber, the predominant grade used in hardwood pallets, yielded 42 percent Grade 2 and better parts, with 33, 16, and 9 percent in Grades 3, 4, and 5 respec-

Figure 1.—Quality distribution of hardwood pallet parts cut from three lumber grades by two cutting methods.

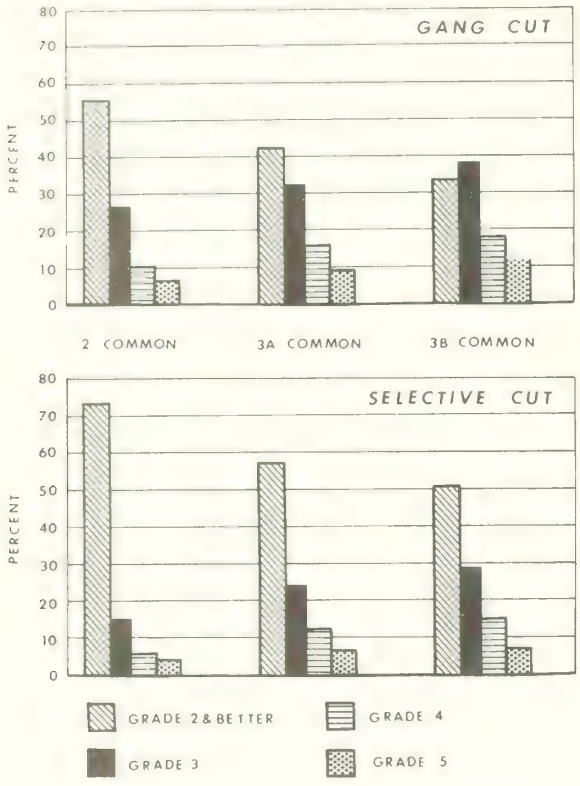



Figure 2.—Quality distribution of hardwood parts gang cut from pallet grade lumber in the North and South.

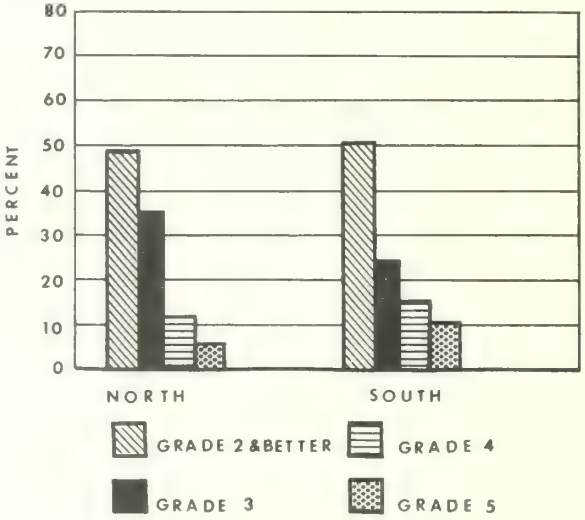
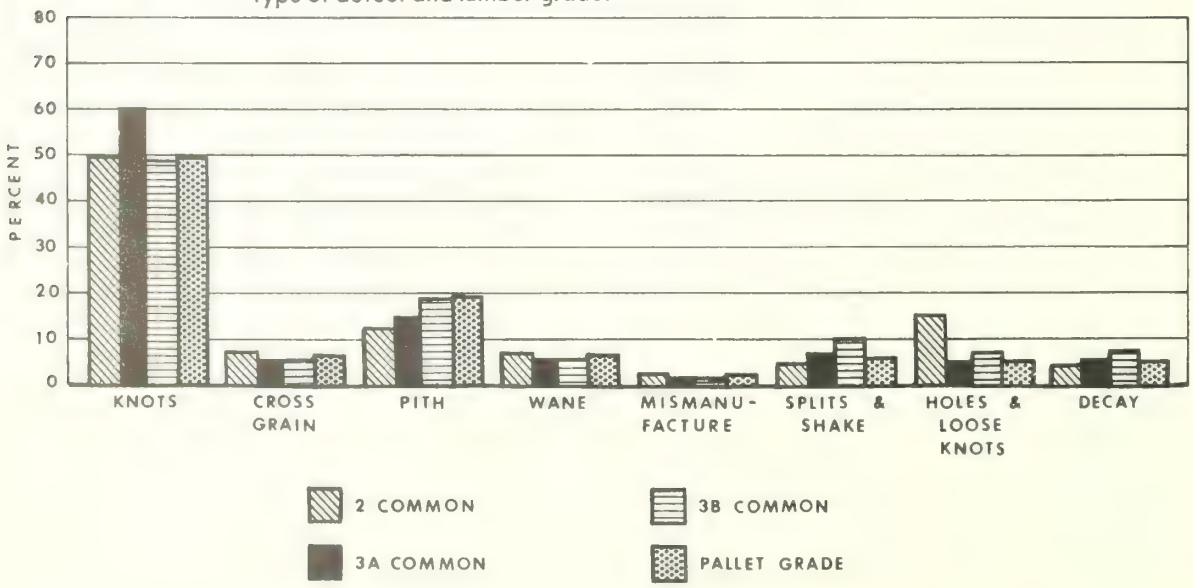



Figure 3.—Distribution of downgraded hardwood pallet parts by type of defect and lumber grade.



tively (fig. 1). Gang-cut No. 2 Common lumber yielded 56 percent Grade 2 and better parts, while 3B Common yielded 32 percent Grade 2 and better parts.

The three selectively cut samples of No. 2 Common, 3A Common, and 3B Common lumber yielded 74, 58, and 50 percent respectively Grade 2 and better parts.

The quality distribution of gang-cut parts from pallet grade lumber and cants closely resembled the distribution of gang-cut parts from 3A Common lumber (fig. 2). These similar distributions confirm the opinion of the pallet manufacturers that 3A Common grade comprises the major portion (approximately 60 percent) of the pallet grade category. Gang-cut pallet-grade lumber in the North yielded 48, 36, 11, and 5 percent in part Grades 2 and better, 3, 4, and 5 respectively. Gang-cut pallet-grade lumber in the South yielded 50, 25, 15, and 10 percent in part Grades 2 and better, 3, 4, and 5 respectively.

### Defect Characteristics

The defects evaluated in the grading process consisted of knots, wane, pith, cross grain, splits and shake, holes and loose knots, decay, and mismanufacture. A defect severity scale relating these characteristics to the grades is included in the appendix.

Knots were the most frequent cause of downgraded parts (fig. 3). The percentage of parts downgraded because of knots ranged from 48 percent in parts cut from 3B Common to 61 percent in parts cut from 3A Common.

Pith was another major cause of downgrading, accounting for 19, 18, 15, and 12 percent of the defects in the parts cut from pallet grade, 3B Common, 3A Common, and 2 Common, respectively.

## SOUTHERN PINE

Southern pine pallet parts were graded at two locations in the South. At one location the parts were cut from mill-run boards and dimension produced from small diameter logs. At the other location the parts were cut from No. 3 Grade dimension. Additional data on the quality distribution of parts cut from No. 2 Grade dimension is available from the PEP research study report[1] and included here for comparative purposes (table 2).

Table 2.—Summary of southern pine sample

| Lumber grade | Total no. of parts graded | Total volume (bd. ft.) |
|---|---|---|
| Mill-run | 1,554 | 1,935 |
| No. 3 Dimension | 2,318 | 1,779 |
| No. 2 Dimension | 1,500 | 2,353 |
| Total | 5,372 | 6,067 |

The quality distribution of southern pine parts was similar to that of eastern hardwood (fig. 4). Number 2 Grade dimension yielded 62 percent Grade 2 and better parts while No. 3 Grade dimension yielded only 36 percent. The mill-run sample was intermediate, with 51 percent Grade 2 and better parts.

The distribution of downgraded parts by type of defect is shown in figure 5. Knots were by far the most frequent cause of downgrading, accounting for 90, 87, and 72 percent of the downgraded parts in the No. 2, mill-run, and No. 3 Grades respectively. The remaining defect categories were cross-grain, pith, and miscellaneous defects which included wane, splits and shake, holes and loose knots, and mismanufacture. The cross-grain, pith, and miscellaneous defects accounted for a relatively small percentage of the total number of downgraded parts.

## DOUGLAS-FIR

Methods of producing pallet parts on the West Coast are radically different from those used in the Eastern United States.

A majority of the deckboards are cut from 8/4 Economy and Utility grade Douglas-fir and hemlock dimension. The 8/4 stock is resawn to produce lumber 11/16 to ¾ inch thick. The lumber is then selectively cut into deckboards of the desired length.

Parts were graded at two locations on the West Coast. At one mill the resawn dimension was regraded and the resulting Construction Grade lumber was sold to the construction industry. The remaining lumber was processed into deckboards and sorted into two use classes—permanent and expendable. At the other location, all of the resawn dimension was proc-

Figure 4.—Quality distribution of southern pine pallet parts gang cut from three lumber grades.

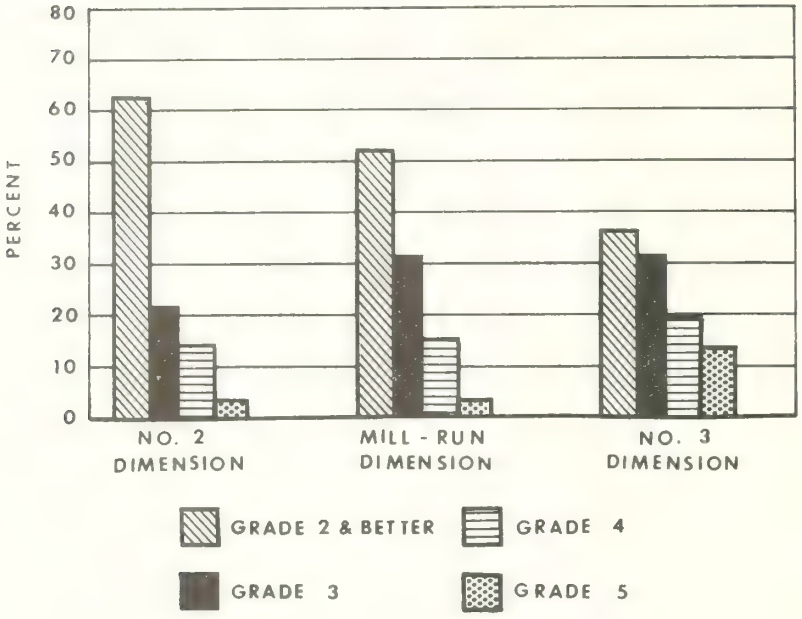
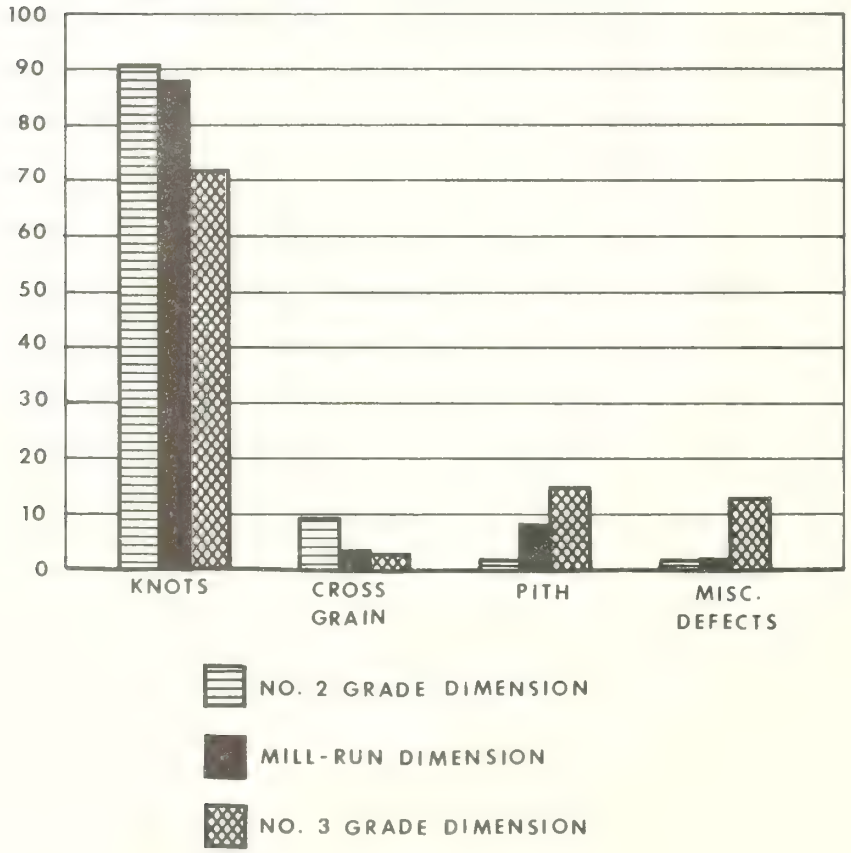



Figure 5.—Distribution of downgraded southern pine pallet parts by type of defect and lumber grade.



essed into deckboards and sorted into three use classes—clear, permanent, and expendable.

Clear quality parts are used in speciality products such as crates, bins, and boxes and do not normally go into warehouse pallets. Permanent quality parts are generally used in returnable or permanent pallets. The expendable parts are of very low quality, with knots, decay, and cross-grain the predominant types of defects. These parts are used exclusively in the assembly of nonreturnable, one-trip pallets. Because of this use classification, our grading efforts were concentrated on permanent quality parts.

Records collected over a 2-year period at one of the mills show that Economy grade dimension will yield 10, 30, and 30 percent in clear, permanent, and expendable quality parts, respectively, with 30 percent waste. The same records show that Utility grade dimension will yield 20, 60, and 10 percent in clear, permanent, and expendable quality, respectively, with 10 percent waste. Thus, only 40 percent of the Economy grade and 80 percent of the Utility grade dimension will yield parts suitable for permanent warehouse pallets.

The total sample consisted of 2,449 parts, a volume of 4,250 board feet (table 3).

The permanent quality component of both Economy and Utility grade lumber yielded 54 percent Grade 2 and better parts with 27, 10, and 9 percent in Grades 3, 4, and 5 respectively (fig. 6). The inclusion of the clear quality component (or the upgraded Construction grade lumber) in the total permanent mix would increase the amount of Grade 2 and better parts by 11 percent.

The distribution of downgraded parts by type of defect is shown in figure 7. Knots were the most frequent cause of downgrading, accounting for 56 percent of the downgraded permanent quality parts. Decay, cross grain, and holes were other major causes of downgrading, accounting for 16, 10, and 9 percent, respectively, of the defective parts.

Figure 6.—Grade distribution of "permanent" quality Douglas-fir pallet parts.

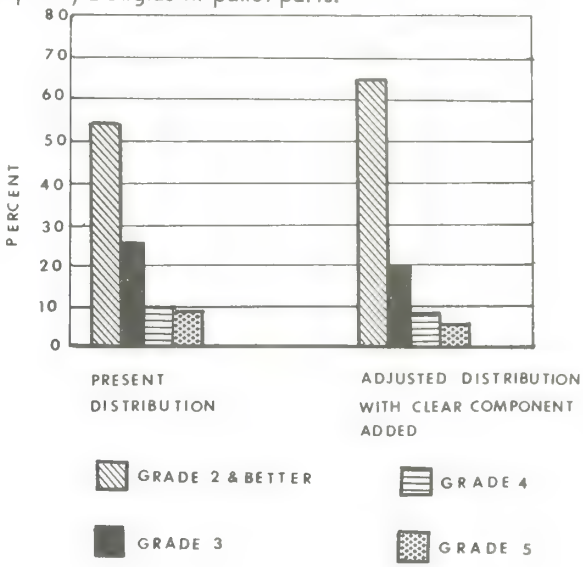



Figure 7.—Distribution of downgraded "permanent" quality pallet parts cut from Douglas-fir lumber.

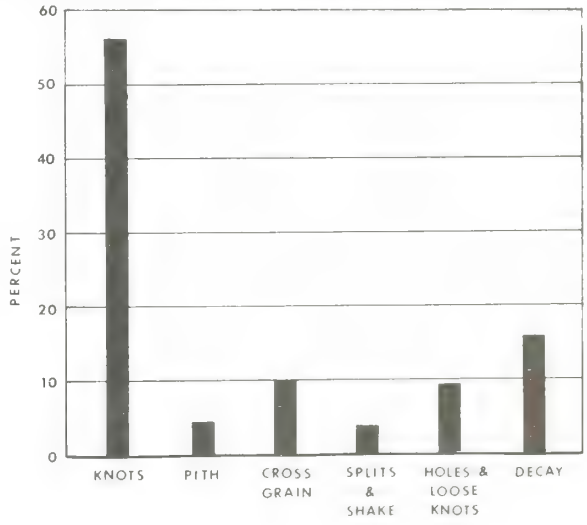



Table 3.—Summary of Douglas-fir sample

| Lumber grade | Use class | Total no. of parts graded | Volume (bd. ft.) |
|---|---|---|---|
| Economy | Permanent | 1,618 | 2,784 |
| Utility | Permanent | 831 | 1,466 |
| Total | | 2,449 | 4,250 |

Two hundred Douglas-fir and 100 hemlock 3- by 4- by 48-inch stringers were graded at one mill. The stringer stock had been manu-

factured and sorted in the normal production process of the mill. The grade composition of the Douglas-fir stringers was 42 percent Grade 2 and better, 19 precent Grade 3, 25 percent Grade 4, and 14 percent Grade 5. The hemlock had 63 percent Grade 2 and better, 12 percent Grade 3, 9 percent Grade 4, and 16 percent Grade 5 parts.

### WESTERN HARDWOOD

A limited amount of tanoak lumber is used in pallet assembly on the West Coast. Tanoak is available in limited quantities and as a result has restricted commercial use. The strength of tanoak is comparable to that of the more dense eastern hardwoods commonly used in pallet assembly. Because of its strength, tanoak could be used in small-order speciality pallets requiring hardwood, or to reinforce softwood pallets.

A small sample of tanoak parts was graded at one mill. The parts were selected at random from an experimental lot produced at a commercial sawmill to the same specifications as Douglas-fir stock. The parts were cut from Grade 3 and better lumber and comparable in quality to the parts cut from 2 Common eastern hardwood lumber. The quality distribution of the tanoak parts is shown in table 4.

Table 4.—Quality distribution of tanoak pallet parts

| Parts | No. of pieces | Bd. ft. | Part distribution | | | |
|---|---|---|---|---|---|---|
| | | | Grade 2 & better | Grade 3 | Grade 4 | Grade 5 |
| | | | Percent | | | |
| Stringers | 150 | 400 | 67 | 20 | 9 | 4 |
| 6-inch Deckboards | 100 | 167 | 50 | 29 | 13 | 8 |
| 4-inch Deckboards | 125 | 139 | 60 | 20 | 16 | 4 |

## CONCLUSIONS

This survey was conducted for the primary purpose of determining the quality distribution of pallet parts cut from low-grade eastern hardwood, southern pine, and Douglas-fir lumber and dimension now being used for permanent warehouse pallets. The following conclusions are indicated:

- There is sufficient amounts of high quality deckboards (Grade 2 and better) in existing pallet lumber mixtures to permit the placement of these parts in the vulnerable peripheral areas of the assembled pallet.

  If the quality distribution of stringers is comparable to that of deckboards, the placement of Grade 2 and better stringers in outside positions (66 percent of the total stringer volume) will require selective cutting, the use of higher grade lumber, lumber sorting, or some other method of improving the quality mix.
- There is a significant difference in the quality distribution of pallet parts cut from different grades of hardwood lumber.
- There is no appreciable difference in the quality distribution of pallet parts cut from different species of comparable quality.
- The cutting method employed has a significant effect on the quality distribution of the parts. The selective method yields a higher quality mix, and a lower output per man-hour.

# APPENDIX

## SUMMARY OF PALLET PART GRADING RULES

Wood characteristics such as pin knots, stain, small surface checks, mineral streaks, and pin worm holes that do not affect strength were not considered as defects.

(a) Knot size—The knot diameter relative to the width of the part determines the grade as follows:

Knot diameter $\leq$ 1/4 part width — Grade 2 and Better
Knot diameter $>$ 1/4 but $\leq$ 1/3 part width — Grade 3
Knot diameter $>$ 1/3 but $\leq$ 1/2 part width — Grade 4
Knot diameter $>$ 1/2 part width — Grade 5 (or Cull)

(b) Number of knots — Knots separated by more than 3 inches are considered as separate defects, otherwise the combined diameters of clusters of knots cannot exceed the limitations established in "a."

(c) Edge knots
(d) Knots in nailing area
(e) Knots above stringer notch

} Reduce grade based on knot size by one grade.

(f) Splits, shake, and pitch streaks

Sum of lengths $\leq$ 1/4 the length of the part — Grade 2 and Better
Sum of lengths $>$ 1/4 but $\leq$ 1/2 the length of the part — Grade 3
Sum of lengths $>$ 1/2 but $\leq$ 3/4 the length of the part — Grade 4
Sum of lengths $>$ 3/4 the length of the part — Grade 5 (Cull)

(g) Cross grain

Slope of grain $\leq$ 1:10 — Grade 2 and Better
Slope of grain $>$ 1:10 but $\leq$ 1:8 — Grade 3
Slope of grain $>$ 1:8 but $\leq$ 1:6 — Grade 4
Slope of grain $>$ 1:6 — Grade 5

(h) Wane in deckboard or stringer — wane is measured in units of 1/256 of the cross-sectional area.

Wane $\leq$ 16 units — Grade 2 and Better
Wane $>$ 16 but $\leq$ 32 units — Grade 3
Wane $>$ 32 but $\leq$ 48 units — Grade 4
Wane $>$ 48 units — Grade 5

(i) Decay

None allowed — Grade 2 and Better
Occupying $\leq$ 1/8 cross-sectional area—Grade 3
Occupying $>$ 1/8 but $\leq$ 1/4 cross-sectional area—Grade 4
Occupying $>$ 1/4 cross-sectional area — Grade 5

(j) Knot holes and loose knots

Hole diameter $\leq$ 1/8 the width of the part — Grade 2 and Better
Hole diameter $>$ 1/8 but $\leq$ 1/6 the width of the part — Grade 3
Hole diameter $>$ 1/6 but $\leq$ 1/4 the width of the part — Grade 4
Hole diameter $>$ 1/4 the width of the part — Grade 5

(k) Mismanufacture

Tolerance — Thickness $\pm$ 1/8 inch
Width and length $\pm$ 1/4 inch
Parts exceeding these limits are Grade 5 with no intermediate grade.

(l) Pith

None allowed — Grade 2 and Better
Face pith — Grade 3
Boxed pith — Grade 4
(No Grade 5 associated with pith).

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

# Economic Analysis of the Gypsy Moth Problem in the Northeast

## II. Applied to Residential Property

by Brian R. Payne
William B. White
Roger E. McCay
Robert R. McNichols

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NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Authors

BRIAN R. PAYNE received a bachelor of science degree in forestry in 1961 and a doctor of philosophy degree in agricultural economics in 1969 from the University of California, Berkeley. He received a master of forestry degree in 1962 from Duke University. He joined the USDA Forest Service at the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, in 1962, and transferred to the Southern Forest Experiment Station at Tuskegee Institute, Alabama, in 1968. In 1970 he transferred to the Northeastern Forest Experiment Station at Amherst, Massachusetts, where he is in charge of the environmental forestry work unit.

WILLIAM B. WHITE received a bachelor of arts degree in zoology and botany from Wabash College in 1964 and a master's degree in forest entomology from Purdue University in 1967. He joined the USDA Forest Service's Northeastern Area, State and Private Forestry, at Delaware, Ohio, after graduation. He is presently on the forest pest management staff, U. S. Forest Service, Upper Darby, Pa.

ROGER E. McCAY received his bachelor of science degree in forest management from Iowa State University in 1966 and his master's degree in agricultural economics from the Ohio State University in 1970. He joined the USDA Forest Service's Northeastern Forest Experiment Station survey project for Ohio in 1966. In 1967 he transferred to the forest economics project located in Columbus, Ohio.

ROBERT R. McNICHOLS received an associate degree in forestry from Hocking Technical College in 1970. He joined the USDA Forest Service's Northeastern Area, State and Private Forestry, at Delaware, Ohio, in 1972. He is presently a forest technician working with the gypsy moth at the Stroudsburg, Pa., field laboratory.

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# Economic Analysis of the Gypsy Moth Problem in the Northeast

## II. Applied to Residential Property


### ABSTRACT

Guidelines are presented for determining dollar losses in residential property values from tree mortality caused by the gypsy moth. The method is based on an earlier study in Amherst, Massachusetts, of the contribution of trees to property values. For each target area, the method requires data on property value, lot size, and number of trees 6 inches dbh and larger for a sample of residential properties. Also required are predictions of tree mortality from a gypsy moth attack.

## INTRODUCTION

THE GYPSY MOTH is an important insect pest affecting trees throughout the northeastern United States. It is particularly destructive in residential areas, where the value of trees for their production of amenities exceeds their value for conversion into wood products. Rational pest control decisions require knowledge of the economic impact of pest attacks, but a measure of the dollar value of trees in residential areas is difficult to obtain. This paper presents a method for evaluating the dollar loss in residential property values from tree mortality caused by the gypsy moth.

The method presented here is based on only one study, and its use is restricted by several assumptions detailed below. Thus, the value estimates this method produces are probably not accurate in many specific locations affected by the gypsy moth. At the same time, the estimates are expected to prove reasonably accurate in the many forested residential areas where this evaluation method is appropriate for use. Until now, no sound method has been available to quantify expected value losses there, and such estimates are urgently needed by federal, state, and local agencies to improve gypsy moth control decisions.

## MEASURING THE CONTRIBUTION OF TREES TO PROPERTY VALUES

The value of trees in residential areas cannot be determined simply by examining market-established prices. Except in limited quantities and in the smallest sizes, these trees are not bought and sold separately from the property on which they grow. The value of trees for conversion into paper, lumber, or firewood is not appropriate for trees that are valuable primarily for their shade and other microclimatic benefits and for their aesthetic contributions. But, to a considerable extent, these benefits contribute to residential property values. This contribution can be measured by comparing the values of properties that have similar characteristics except for their tree cover.

A recently completed study[1] has measured the contribution of trees to residential property values in Amherst, Massachusetts. There, trees contribute an average of 7 percent and as much as 15 percent to the value of $25,000 to $50,000 homes on lots averaging 20,000 square feet. This contribution comes only from trees 6 inches dbh and larger. The relationship of value contributed by trees (V) to number of trees 6 inches dbh and larger (t) has the following form:

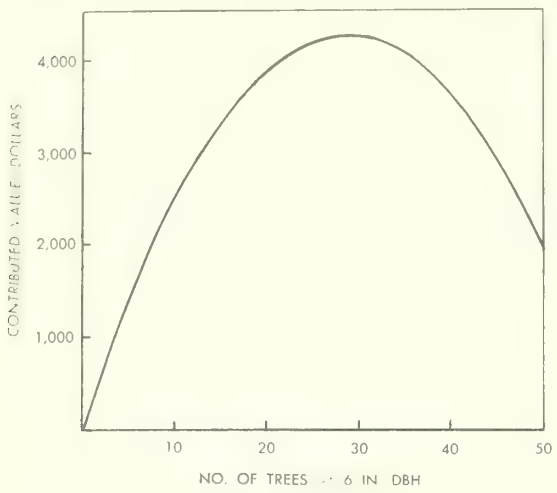
$$V = 300\,t - 5.22\,t^2 \text{ for } 0 < t < 50, \text{ and}$$
$$V = 1950 \text{ for } t \geq 50$$

Thus, value added by trees increases at a decreasing rate to a maximum value of $4,310 with 29 trees (fig. 1). Because the Amherst study included no properties with more than 50 six-inch and larger trees, the curve shown in figure 1 is truncated at that point, and the value contributed by 50 or more trees is assumed to be a constant $1,950. The values shown in figure 1 are listed in table 1 as an aid in calculating pre-attack and post-attack tree values.

To test the predictive ability of the Amherst property value equations and to develop a method for applying one or more of these equations to the estimation of losses caused by the gypsy moth, we selected a sample of properties near Stroudsburg, Pennsylvania, an area

[1]Payne, Brian R. (unpublished) The contribution of trees to residential property values in Amherst, Massachusetts. (Manuscript in process; Study Plan on file, USDA Forest Service, Northeastern Forest Experiment Station, 101 Flint Laboratory, University of Massachusetts, Amherst. )

Figure 1.—Contribution of trees to property value on lots averaging 20,000 square feet.




heavily infested with gypsy moths. Time and manpower limitations prevented a replication of the Amherst study; thus, we assumed that the coefficients for independent variables were applicable in Stroudsburg, and we tested the predictive ability of the entire equation. The range of property values was wider in Stroudsburg than in Amherst, as low as $7,000 and as high as $42,000. Although the Amherst equations overvalued properties at the low end of this range and undervalued properties at the high end, the average predicted value was nearly identical with the average observed value. Furthermore, the percentage of property value contributed by trees was within the range found in the Amherst study.

The field methods and calculation procedures developed as a result of the Stroudsburg test are presented below as a set of guidelines.

## GUIDELINES FOR CALCULATING VALUE LOSSES

Loss of property value from tree mortality caused by the gypsy moth is predicted by (1) calculating the pre-attack value of trees, (2) predicting tree mortality from a specified level of gypsy moth attack, and (3) calculating the post-attack value of the remaining trees. Value loss is the difference between pre-attack and post-attack values.

This method assumes that the results of the Amherst study can be applied directly to the target area for which value loss estimates are to be made. Therefore, the method should be used only for residential property, that is, for lots with houses on them. Ideally, trees should be well distributed on each property rather than massed in only one area. Individual lot sizes should not be much smaller than ¼ acre or much larger than 1 acre, and the observed number of trees must be adjusted to a 20,000-square-foot lot-size basis. If possible, the value of properties should not be less than $25,000 or more than $50,000.

### Collect Field Data

For each target area, select a sample of residential properties, and collect the following data for each property.

(1) Fair market value.
(2) Lot size in square feet.
(3) Number of trees 6 inches dbh or larger.
(4) Data required to predict tree mortality from gypsy moth attack.

The number of properties selected for the sample will depend on the precision of estimation desired and the inherent variability of the population being sampled. Calculate sample size following standard statistical practice; see, for example, Freese *(1967)* or consult a statistician.

Fair market value estimates are needed for two reasons: (1) to determine whether properties fall within the $25,000 to $50,000 range as in the Amherst study, and (2) to calculate the percentage contribution of trees to property value, as a check on the reasonability of the absolute values calculated.

The fair market value of each property is the value that it would bring if sold. Recent selling prices will not be available for most properties. However, local real estate appraisers can be asked to estimate the current value of each sample property. Depending on his knowledge of the local market, an appraiser should be able to estimate value fairly accurately by visiting each property for a few minutes but without entering the houses.

Interviewing homeowners is an alternative means of determining property values, but this method is more expensive and will produce less consistent results than realtor appraisals. Assessed values are relatively easy to obtain,

but they are generally poor estimates of current fair market values.

Lot size in square feet can be obtained by pacing property lines, by examining subdivision plans, or by identifying and measuring properties on large-scale aerial photographs.

Number of 6-inch or larger trees can be obtained by simple count with an "eyeball estimate" of minimum diameter. On many lots, this count can be made while pacing boundary lines. With more than 50 six-inch or larger trees per 20,000 square feet (approximately ½ acre), estimate their number to the nearest 5 or 10 trees.

Additional field data may be required to predict mortality from gypsy moth attack. Such predictions are outside the scope of this report, but a later paper in this series will provide a method of mortality estimation based on tables developed by Campbell and Valentine *(1972)*. Use of their tables requires observation of stand condition, tree species and dominance class, and a knowledge of an area's past history of attack.

### Calculate Pre-Attack Value of Trees

To calculate the pre-attack value of trees for each property, adjust the observed number of 6-inch and larger trees to a 20,000-square-foot lot-size basis, using the following formula:

$$AT = OT\left[\frac{20{,}000}{LS}\right]$$

where: AT = adjusted number of trees
OT = observed number of trees
LS = observed lot size in square feet

Use table 1 to find the dollar value of the adjusted number of trees.

As a check on the reasonability of the values taken from table 1, calculate the percentage that trees contribute to the value of each property. If a substantial number of these exceed 15 percent, or if the average for all sample properties exceeds 15 percent, the values in table 1 are probably too high and should be adjusted downward. This problem is likely to occur with low valued properties, those below $25,000.

Observed and calculated values for lot size, number of trees, and tree values can be entered in a table similar to that shown in table 2.

### Calculate Post-Attack Value of Trees

To calculate the post-attack value of trees, estimate the percentage or number of trees on each sample property that would be killed by a specified gypsy moth attack. Such an estimate may be based on field studies that accurately predict expected mortality, or it may be a best guess based on judgment and experience. Or, several levels of mortality may be postulated and the value of losses calculated for each level.

Enter estimated mortality of trees 6 inches and larger in column 6 of table 2. Subtract this number from the observed pre-attack number

Table 1.—Contribution to residential property value from trees 6 inches dbh and larger

| No. of trees | Dollar value | No. of trees | Dollar value | No. of trees | Dollar value |
|---|---|---|---|---|---|
| 0 | $ 0 | 17 | $3,590 | 34 | $4,160 |
| 1 | 290 | 18 | 3,710 | 35 | 4,100 |
| 2 | 580 | 19 | 3,810 | 36 | 4,030 |
| 3 | 850 | 20 | 3,910 | 37 | 3,950 |
| 4 | 1,120 | 21 | 4,000 | 38 | 3,860 |
| 5 | 1,370 | 22 | 4,070 | 39 | 3,760 |
| 6 | 1,610 | 23 | 4,140 | 40 | 3,650 |
| 7 | 1,840 | 24 | 4,190 | 41 | 3,520 |
| 8 | 2,070 | 25 | 4,240 | 42 | 3,390 |
| 9 | 2,280 | 26 | 4,270 | 43 | 3,250 |
| 10 | 2,480 | 27 | 4,290 | 44 | 3,090 |
| 11 | 2,670 | 28 | 4,310 | 45 | 2,930 |
| 12 | 2,850 | 29 | 4,310 | 46 | 2,750 |
| 13 | 3,020 | 30 | 4,300 | 47 | 2,570 |
| 14 | 3,180 | 31 | 4,280 | 48 | 2,370 |
| 15 | 3,320 | 32 | 4,250 | 49 | 2,160 |
| 16 | 3,460 | 33 | 4,210 | 50 | 1,950 |

Table 2.—Worksheet for calculating value losses

| Property number | Lot size, sq. ft. | Pre-attack | | | Mortality in No. of trees | Post-attack | | | Loss in dollars |
|---|---|---|---|---|---|---|---|---|---|
| | | No. of trees ≥ 6″ | | Value in dollars | | No. of trees ≥ 6″ | | Value in dollars | |
| | | Observed | Adjusted | | | Observed | Adjusted | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
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| | | | | Σ (5) | | | | Σ (9) | Σ (10) |

of trees per property shown in column 3. The result, entered in column 7, is observed post-attack number of trees per property. Adjust this number for lot size as before, and enter the result in column 8 of table 2.

Again refer to table 1 for the value of the adjusted number of trees. Enter this value in column 9 of table 2.

### Calculate Value Loss

The values entered in table 2 are used to estimate the potential or expected property value loss for a target area or community. Calculate the total pre-attack value of trees for the target area by summing the values for the sample properties (column 5), and expand the sample values to population values. For example, if a simple random sample of 5 percent of residential properties in a community has been selected, the pre-attack property value of trees in the community will be 20 times the total value for the sample. Similarly, calculate the total post-attack property value of trees (sum of column 9), and subtract it from the pre-attack value. The result is an estimate of property value loss due to the gypsy moth.

An alternative calculation will yield the same answer. Calculate the loss for each sample property by subtracting post-attack value from pre-attack value, and enter the result in column 10 of table 2. Calculate the total loss for sample properties and expand this figure to a population value.

With either calculation method, the result is the loss in residential property value from tree mortality caused by the gypsy moth, for the entire community. If desired, this value can be converted to a per acre value by dividing the total loss by the total residential acreage within the community.

### Interpretation of Calculated Losses

It is possible that this method of estimating losses will produce negative values, either for sample properties or for an entire community. That is, tree mortality may result in higher property values. As shown in figure 1, the contribution of trees to property values is a maximum with 29 six-inch or larger trees on a property of 20,000 square feet. Thus, if the gypsy moth reduces the adjusted number of trees to the 29 to 49 range, estimated property value will rise. If the gypsy moth kills trees but leaves at least 50 on a 20,000-square-foot lot, estimated property value will be unchanged.

Property value losses (or gains) estimated by this method are those expected to occur in the absence of control measures. These potential losses provide a partial basis for deciding what level of control is economically justified.

Also needed for control decisions is cost-effectiveness information for alternative methods of control. If control effectiveness can be measured in terms of a reduction in tree mortality, the method described here can be used to convert this measure of effectiveness into a dollar value.

## CONCLUSIONS AND LIMITATIONS

The method presented here for estimating property value losses from gypsy moth attack is appropriate only for residential property. The values given in table 1 are not appropriate for parks or other forested tracts not used for homes. Furthermore, the method is appropriate for only that type of residential property characterized by a home located in the midst of large trees. Thus, lots cleared of trees for home building, with woodland remaining at the rear of the property, are not appropriate for economic evaluation by this method.

Our method does not account for values of trees that are not realized by owners of private properties. These might include offsite benefits, such as microclimatic effects on nearby land or aesthetic benefits to neighbors or passers-by. In particular, the values used here are not appropriate for single specimen trees: trees that are very large or very old, and that are situated so as to provide outstanding beauty or other amenities to their surroundings. These trees can be better evaluated by using the formula of the International Shade Tree Conference *(1970)*.

Calculation of property value losses due to the gypsy moth includes only those losses from tree mortality. No effects on value from reduced tree vigor or the unsightly appearance of defoliated trees are included. Neither is the nuisance value of gypsy moth caterpillars, but this nuisance may cause more concern to some homeowners than the loss of a few trees. Often,

dead trees must be removed, but this cost is not considered here. Thus this method underestimates the true cost of a gypsy moth attack in residential areas. But it does provide objective estimates of one important segment of this cost.

Future research will provide more refined estimates of the dollar value of losses to the gypsy moth in residential areas, but even our crude estimates of the value of residential trees are surprisingly high relative to timber values. Thus, we believe that more expensive and more selective control measures are justified for gypsy moth control in residential areas than in timber-producing areas.

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# A Silvicultural Guide for Developing A SUGARBUSH

by Kenneth P. Lanctot
Russell E. Walters
Frederick M. Lamb
Raymond T. Fowler

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NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082

Resource Management, for the Northeastern Area, State and Private Forestry, USDA Forest Service.

RUSSELL S. WALTERS is a Research Forester at the Sugar Maple Laboratory of the Northeastern Forest

FREDERICK M. LAING is Research Associate in the Department of Botany at the University of Vermont.

RAYMOND T. FOULDS is Extension Forester at the University of Vermont.

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# A Silvicultural Guide for Developing A SUGARBUSH

**Abstract**

A practical guide for the management of a sugarbush. Guidelines are established for the manipulation of stand density and stocking to promote the development of healthy vigorous trees with deep, wide crowns, the necessary attributes for highest possible yield of sugar-rich sap. Specific treatments are prescribed for sapling, poletimber and small sawtimber stands and a procedure is provided for testing a sugarbush for sweetness, to select trees for thinning.

WITH A STRONG demand for maple syrup—and healthy prices—a commercial sap or syrup operation seems to be a very promising venture for a landowner. Sugarbush management is one technique for improving profit potential by increasing the yield of sweet sap. Even greater financial returns are possible by combining management with new methods of sap collection and processing.

We have established management guidelines for each size class of trees to help maximize gains from the sugarbush. These recommendations are based on silvicultural observations and experience, current research, and related literature.

In sapling stands, the crop tree selection method is recommended. In pole stands and larger, stocking should be reduced to a point that would be considered understocked for timber production. This will promote rapid crown expansion and provide an acceptable level of sap production.

## Background

Maple syrup is one of this country's oldest agricultural commodities. When the first settlers arrived in this country, Indians were using maple sugar as an important food item. The settlers eagerly adopted the Indians' source of sugar, and through the years maple sugar became an important article of diet.

Maple sugar production increased rapidly in this country until about 1860, when the cheaper cane sugar gradually began to replace maple sugar. Since then, except for an increase during World War I, production has been on the decline. Presently, very little sugar is being produced. The major emphasis is on syrup production. In 1971, 962,000 gallons of syrup were made. This was the smallest amount produced in any year since yearly estimates were begun in 1916.

The production of maple syrup has always been a farm enterprise, and recently has

proven to be a most profitable one. With the decline in the number of farms and in the active farm maple groves or sugarbushes, the opportunity has not diminished. In fact with modern equipment—plastic tubing, mechanical tapping tools, etc.— the opportunity has increased. The decline in production has brought record prices, so that profit potential for both the sap and syrup producer is now greater than ever before.

Sap collection accounts for 40 percent or more of the cost of syrup production. Reducing this cost would have a strong influence on the returns from a syrup operation. Using trees that produce a high volume of sap with high sugar content reduces the cost of handling the sap necessary to produce a given amount of syrup. These high-producing trees develop by good management of sugar maple stands and not by chance.

To manage a sugarbush effectively, it is essential to know the characteristics of a tree that will produce large volumes of sugar-rich sap. Research has shown that the ideal sugarbush tree is a vigorous, fast-growing tree that has a deep, wide, fully developed crown exposed as much as possible to sunlight. It has also demonstrated that sugar maples possessing these characteristics tend to produce sweeter sap and greater quantities of sap than slower-growing, smaller-crowned trees. Trees with larger crowns have greater leaf surface area and therefore have a greater capacity to carry on photosynthesis—the mechanism that produces the carbohydrates, or sugar, stored within the tree.

Sap production per tree increases with live crown ratio, width of crown, and rate of diameter growth. In a study conducted by the Ohio Agricultural Experiment Station *(Moore et al. 1951)*, the effects of these factors were identified. Trees with crowns averaging 50 to 75 percent of the total height yielded about 25 percent more sap than similar trees with a crown ratio of less than 50 percent.

Width of crown had a more dynamic effect. Trees with crowns over 30 feet wide, crowns characteristic of trees in an open stand, produced over 100 percent more sap than trees having the same stem diameter but with crowns less than 20 feet wide, a crown size typical of forest-grown trees. Growth rate, which is related to crown size, is strongly correlated with sap yields. Moore et al., found that trees with a growth rate of 5 to 10 rings per inch yielded about 30 percent more sap than trees growing at the rate of 15 to 20 rings per inch.

It has long been known by those familiar with the maple business that some sugar maple trees are "sweeter" than others. Why some trees produce sweeter sap has been a matter of study for several years. Although some of the variability among trees can be attributed to genetic differences, environmental factors such as live crown ratio, crown diameter, and crown exposure all play a significant role.

Stevenson and Bartoo *(1940)*, who reported on extensive sweetness studies in Pennsylvania, found that forest-grown trees produce sap about 30 percent lower in sugar content than open-grown trees. The sugar content of forest-grown trees averaged about 2.25 percent, in contrast to 3.34 percent for open-grown trees. Moore et al. *(1951)* and Morrow *(1955)*, substantiated this correlation. Their reports indicate that open-grown trees are about 15 to 20 percent sweeter than forest-grown trees.

These known facts about sap sweetness and sap yields can easily be incorporated into field practice by careful tree selection. Ideally, trees that are inherently sweet should be identified early, when they are small, and thinnings should be made frequently to allow them to grow and expand rapidly. Identifying the sweeter trees in young stands and favoring them by judicious thinning can greatly improve sap production.

## Managing the Sugarbush

The objective of sugarbush management is to produce the highest possible yield of sugar-rich sap per acre. This is accomplished through the manipulation of stand density and stocking to foster the development of healthy, vigorous trees with deep, wide crowns.

Although much has been written on the subject, two publications "A Guide to Sugarbush Stocking", by Smith and Gibbs *(1970)* and

"Standards for Maple Sugarbush Management in Vermont", by Foulds et al. *(1956)* probably have the greatest applicability. Both papers summarize existing knowledge on the subject and both are based on maximum crown size related to tree diameter and number of trees per acre. The recommendations that follow are based essentially on the information presented in these two papers and other pertinent data, and expanded to include a technique of stand analysis not dissimilar to timber management. In fact, the method suggested uses the same stand-examination methods and prescription-writing procedures used in timber management *(Leak et al. 1969)*.

The "Diagnostic Tally Sheet for Sugarbush Stands" (Table 1) provides the means of gathering the data necessary for making sound management decisions. The tally is used to determine the number of trees and basal area per acre, the necessary ingredients of the "Stocking Chart" (fig. 1) for even-aged northern hardwoods. The chart provides the means of comparing existing stand stocking with the suggested stocking levels for increased sap yield. For example, in figure 1, the B level represents minimum stocking for timber objectives. The C level is considered as understocked for quality timber production, but in pole and larger stands not previously thinned it is an acceptable level for improving sap production. The S level is the minimum stocking for maximum crown development with full utilization of crown space. However, this ideal crown development is attainable only if management is started early in the life of the stand—at sapling or small pole size—and carried to stand maturity.

## Field Procedures and Prescriptions

### I. Stand Analysis

In sapling stands averaging between 2 and 4 inches in diameter, the intent of stand analysis is to determine if there are enough maple trees for management. This assessment can usually be made by a cursory observation. A stand is adequately stocked if there are 80 to 100 well distributed sugar maple trees per acre.

For stands averaging 6 inches in diameter and over, use the "Diagnostic Tally Sheet for Sugarbush Stands." Take 4 to 10 sample points with a 10-factor prism and count only trees in the main crown canopy, the intermediate to dominant trees. Record the trees by diameter class in the proper block of the cumulative tally. Summarize plot data and determine the total number of trees and basal area per acre for the stand. Use the stocking chart to determine the basal area at the C level or the level selected for management. Insert data under stand description and use it as the basis of a stand prescription.

### II. Stand Prescription

1. Saplings

   Thinning should start early in the life of the stand when trees average 2 to 4 inches in diameter, and should be made at 5 to 10-year intervals. Early thinning encourages the development of large side branches and increases rapid diameter growth. It is at this young age that deep crowns can be maintained or developed most successfully.

   The crop tree selection method can be applied quite successfully in these stands. In writing the prescription consider the following:

   a. To insure adequate stocking of about 80 to 100 trees when the stand reaches an average size of 10 inches in diameter, select 100 to 125 dominants or co-dominants with good stem and crown forms, free of defects such as acute forking.

   b. Favor the sweet tree. Use a sugar refractometer (fig. 2) to measure the amount of sugar in the sap. For testing a sugarbush for sweetness, follow the field procedure suggested in the next section.

   c. Free of the crowns of the selected crop trees on all sides to create openings between crowns of 6 to 7 feet.

Table 1.—*Diagnostic tally sheet for sugarbush stands*

[For the determination of the number of trees per acre, average stand diameter, stocking, and spacing for sugarbush management]

| Dbh (inches) | Number of trees tallied | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 2 | 458 | 917 | 1375 | 1834 | 2292 | 2750 | 3209 | 3667 | 4125 | 4584 | 5042 | 5501 | 5959 | 6417 | 6876 |
| 4 | 115 | 229 | 344 | 458 | 573 | 688 | 802 | 917 | 1031 | 1146 | 1260 | 1375 | 1490 | 1604 | 1719 |
| 6 | 51 | 102 | 153 | 204 | 255 | 306 | 357 | 407 | 458 | 509 | 560 | 611 | 662 | 713 | 764 |
| 8 | 29 | 57 | 86 | 115 | 143 | 172 | 201 | 229 | 258 | 287 | 315 | 344 | 372 | 401 | 430 |
| 10 | 18 | 37 | 55 | 73 | 92 | 110 | 128 | 147 | 165 | 183 | 202 | 220 | 238 | 257 | 275 |
| 12 | 13 | 25 | 38 | 51 | 64 | 76 | 89 | 102 | 115 | 127 | 140 | 153 | 165 | 178 | 191 |
| 14 | 9 | 19 | 28 | 37 | 47 | 56 | 65 | 75 | 84 | 94 | 103 | 112 | | | |
| 16 | 7 | 14 | 21 | 29 | 36 | 43 | 50 | 57 | 64 | 72 | 79 | 86 | | | |
| 18 | 6 | 11 | 17 | 23 | 28 | 34 | 40 | 45 | 51 | 57 | 62 | 68 | | | |
| 20 | 5 | 9 | 14 | 18 | 23 | 27 | 32 | 37 | 41 | | | | | | |
| 22 | 4 | 8 | 11 | 15 | 19 | 23 | 27 | 30 | 34 | | | | | | |
| 24 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 25 | 29 | | | | | | |
| 26 | 3 | 5 | 8 | 11 | 14 | 16 | 19 | 22 | 24 | | | | | | |
| 28 | 2 | 5 | 7 | 9 | 12 | 14 | 16 | 19 | 21 | | | | | | |
| 30 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | | | | | | |

*Tally Legend*

O

X

*Number of plots*

*No. of trees/acre*

*Total Number of Trees Per Acre.*—Add the last figures checked on each line and divide by the number of point samples tallied.

*BA Per Acre.*—Add the total number of entries in each size class, multiply by 10 and divide by the number of point samples tallied. (BA factor = 10)

STAND DESCRIPTION:

Number of trees per acre____ BA per acre _____ Average stand dbh _____

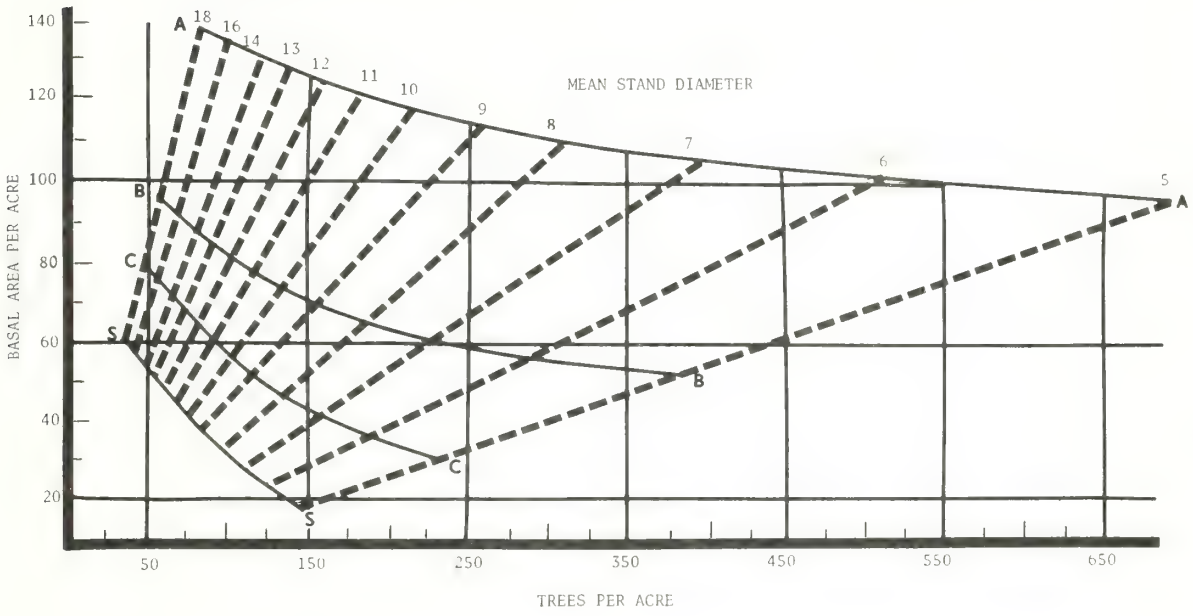
Trees per acre at C level_____ BA at C level_____
(or level selected for management) (or selected level)

STAND PRESCRIPTION:

Mark for cutting or girdling _____ trees = _____ BA (Total minus C or selected level)

Average crop tree spacing _____ feet

Figure 1.—Stocking chart for even-aged northern hardwoods, based on number of trees in the main canopy, average diameter, and basal area per acre. *For timber objectives,* stands above the A line are overstocked. Stands between A and B lines are adequately stocked. Stands between B and C line should be adequately stocked within 10 years. Stands below the C line are definitely understocked. *For sugarbush management,* maple stands at the S line are at minimum stocking levels.



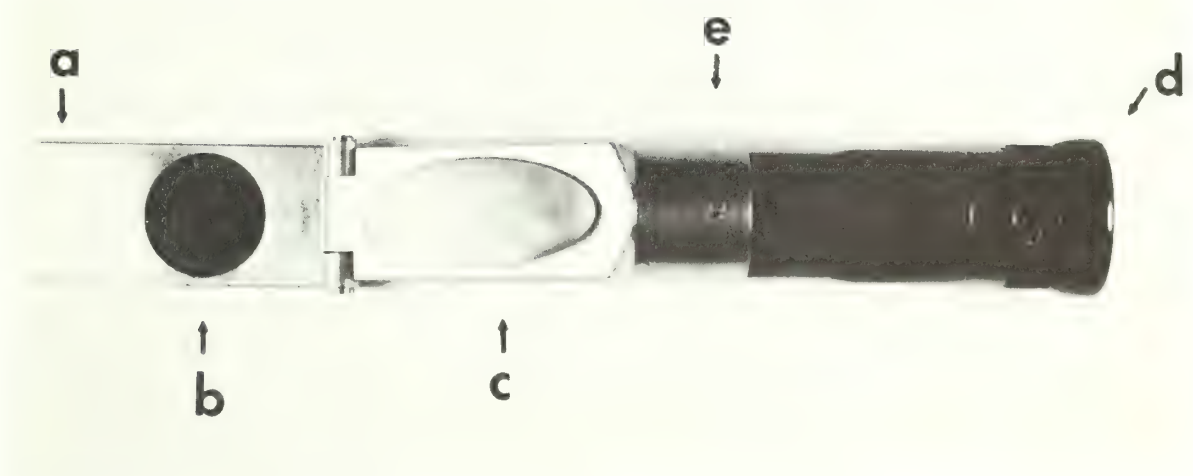




Figure 2.—The sugar refractometer: (a) cover; (b) dark circular area where drop of sap is placed; (c) glass prism; (d) eyepiece; (e) small adjustment screw is used in calibrating the instrument.

d. Select one crop tree within each spacing distance, 20 to 25 feet, and crown release it. Leave trees between the crop trees that are not competing for crown space.

2. Poletimber

The objective in stands of 6 to 10 inches diameter is to improve growing conditions for desirable crop trees by achieving good spacing between crowns. A comparison of present stocking in basal area with the recommended level will provide the basis for a sound prescription for management.

In thinning poletimber stands:

a. Favor the sweet tree as determined by the refractometer measurements made in the fall or spring.

b. In stands previously thinned for crown expansion, reduce the stocking level to bring it between the C and S lines, giving proper consideration to distribution of trees and crown development needs.

c. Stands *not* previously thinned for sap production: Reduce the stocking to the C level. The first thinning of these stands entails some danger of sunscald, insects, and windthrow, but these dangers are minimized if stocking is not reduced below the C level.

3. Small Sawtimber

The greatest immediate response in stands averaging 12 to 15 inches in diameter can be brought about by the increased diameter growth that accompanies crown expansion. Fast growing trees, free to grow, produce significantly more sap than slow-growing competing trees. If these stands are being tapped, there will be a period of reduced sap production after thinning because there are fewer trees to tap. Within a short time, however, sap yield will start to increase, and if conditions are suitable, will continue to do so until production exceeds that before thinning.

In the application of management:

a. Identify the sweetest trees for retention in the stand. Determine sweetness in the fall or during the sugaring season.

b. Reduce the stocking to the C level and strive for an even distribution of stems. If the stand was previously thinned or is sparsely stocked, reduce stocking below the C level and close to the S level to allow for continued expansion of crowns.

4. Large Sawtimber, 15 inches or more

Stands of this size class, grown under forest conditions for the most part, will benefit little from thinning. Any cultural activity should aim to improve the health of the stand by removing decayed sugar maples, trees of other species, and poor-risk trees or trees susceptible to wind breakage. Removal will usually be on a tree-by-tree basis rather than by stocking or spacing.

In overmature stands or stands that need to be regenerated, clearcutting in strips, patches, or groups of ½-acre or more is recommended. The size of the patch or management unit will vary depending on topography and accessibility. In all cases, the opening must be easily identified on the ground and easily managed as a unit.

## Field Procedure for Testing A Sugarbush for Sweetness

The percentage of sugar maple sap may vary considerably during the day as well as from day to day and season to season. To obtain comparable data when testing a group of trees, the testing must be done within a short time. In testing a large number of trees, such as an entire sugarbush, do not try to test all the trees at once. The best method might be to consider the readings from trees tested in a 2-hour period as one group of comparable readings, and readings taken during the next 2-hour period as a separate group. This can

Figure 3.—Testing sugar maple sap for sweetness can be accomplished by collecting a drop of sap for the sugar refractometer. Use an awl (A) to pierce the bark into the wood; insert a hypodermic needle (B) firmly into the wood, or use an ordinary toothpick (C).

be continued as long as the sap flow lasts. Sugar readings can be compared within each group, but comparisons should not be made between groups.

As a flow period begins, sap in some trees will start running before others. At the end of a flow, some trees stop before others. To avoid repeated trips to some trees to obtain a sap sample it is best to wait until the flow has well started before beginning the testing and to stop as soon as a few trees are found to have stopped flowing.

A sugar refractometer should be used for testing sap because it is fast and accurate and requires only a drop of sap to obtain a reading. The simplest way of obtaining a drop of sap is to cut a twig or small branch with pruning shears. On those trees where twigs or small branches are not within reach, a hole must be made in the trunk of the tree. Because sap from twigs give a higher reading than sap from tree trunks, it is important when testing a sugarbush that only one source be used—the twig or the trunk.

In obtaining sap from the trunk, first make a hole through the bark with a sharp awl (fig. 3a). Some sort of device must be inserted in the hole to carry sap away from the tree, and it has been found that a hypodermic needle works very well (fig. 3b). Those with large bores and short stems are the most durable. A good choice would be a 13-gage needle with a 1-inch stem. The needle should be pressed firmly or tapped into the hole. It is important that needles be washed before they are reused.

Whichever method is used, twig or trunk, you can avoid waiting for the drop of sap to appear by working several adjacent trees before testing the sap for sweetness.

With care, sharp toothpicks can be substituted for needles with the same results (fig. 3c). They must be pushed firmly into the wood so they are held firmly. Also, they must rest on the bottom of the hole at the outer edge, otherwise, the sap will run down the bark.

To find the sweetest trees as a guide to thinning a young stand, the first requirement is to establish an average. This can be determined by testing each tree or every second or third tree along a transect. Areas that include any major change in slope or exposure within the sugarbush should be tested separately. The sum of the readings from these sample trees, divided by the number of samples, establishes the working average for that particular testing period. Trees with readings below average should be identified with colored ribbon or

paint spots. In thinning, remove as many of these trees of below-average sweetness as necessary to produce the desired stocking. A separate working average for sample trees should be computed for every 2- to 4-hour testing period, for best results.

Weather conditions play an important part in testing with any of the procedures mentioned above. Rain or snow may permit dilution of the sap drop and give incorrect readings. Moderate or stronger winds may blow the sap drops away or may concentrate the sugar by evaporating some of the water if the drop is exposed very long. The sap will run longer if the needles or toothpicks are inserted on the warmer side of the tree.

## Conclusion

These management guidelines were developed to improve sugarbush profit potential by increasing yields of sweet sap. This is accomplished through manipulation of stand density and stocking to promote development of healthy, vigorous trees with deep, wide crowns. Best results are achieved when management is started at an early age, preferably when the trees are sapling size. Thinnings should not only favor trees with good condition and position but also those with superior sweetness or sugar content.

In sapling stands, the crop tree selection method is recommended. Thinnings in these stands should be light and frequent, no more than 5 to 10 years apart. In pole stands and larger, reducing the stocking to a point that would be considered understocked for timber production will promote rapid crown expansion and maximum sap production.

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# Appendix

## I

*Rules of Thumb*

a. An ideal sugarbush has at least 1000 or more tapholes or 70 to 90 taps per acre.
b. Sap from four tapholes will yield about 1 gallon of syrup per year.
c. The compass location of the taphole is not important.
d. Normal sap yield per tap will range from 5-20 gallons per season. This can be increased to 25 gallons or more by using a vacuum pump.
e. Trees in the 18- to 20-inch diameter class will produce over 50 percent more sap per taphole than 8- to 10-inch trees.
f. "Rule of 86" by Jones (1967). This give the amount of sap required to produce a gallon of syrup at various levels of sap sugar content. As an example, it takes about 86 gallons of sap of 1 percent sugar to produce 1 gallon of syrup. Only 43 gallons of 2 percent sap are required to produce 1 gallon of syrup. In other words, to establish the sap-syrup relationship, divide the percentage of sugar in the sap into 86.

## II

Table 2.—*Number of tapholes that can safely be made in a tree*

| Diameter | Tapholes per tree |
|---|---|
| *Inches* | *No.* |
| Less than 10 | 0 |
| 10-14 | 1 |
| 15-19 | 2 |
| 20-24 | 3 |
| 25 or more | 4 |

## III

Table 3.—*Comparison of average sap flow of sugar maple and soft maple, arranged by diameter classes on basis of number of buckets per tree of both species. Somerset County, Pennsylvania, 1931 (McIntyre)*

| Diameter class | Average number of buckets hung | Sugar maple | Soft maple |
|---|---|---|---|
| | | Average flow | Average flow |
| *Inches* | *No.* | *Quarts** | *Quarts** |
| 9-16 | 1.0 | 8.9 | 5.5 |
| 17-23 | 1.5 | 15.1 | 7.4 |
| 24-28 | 2.2 | 17.7 | 12.5 |
| 29-33 | 2.8 | 22.4 | 13.4 |
| 34-36 | 3.6 | 27.7 | 20.3 |
| 37-45 | 3.8 | 31.7 | 18.9 |

Soft maple trees produce less sap that is less sweet than hard maple trees.

*Sap flow during a short period—not a seasonal flow.

Table 4.—*Number of sugar maple trees per acre and spacing by average stand-diameter class for sugarbush stands at the S level, C level, and B level of stocking*

| Average stand dbh class | S Level | | C Level | | B Level | |
|---|---|---|---|---|---|---|
| | Trees per acre | Tree spacing | Trees per acre | Tree spacing | Trees per acre | Tree spacing |
| *Inches* | *No.* | *Feet* | *No.* | *Feet* | *No.* | *Feet* |
| 6 | 126 | 19 | 160 | 16 | 299 | 12 |
| 8 | 98 | 21 | 140 | 17 | 190 | 15 |
| 10 | 79 | 23 | 105 | 20 | 129 | 18 |
| 12 | 64 | 26 | 86 | 23 | 99 | 21 |
| 14 | 54 | 28 | 76 | 24 | 86 | 23 |
| 16 | 46 | 31 | 70 | 25 | 76 | 24 |

Table 5.—*Example of use of the diagnostic tally sheet for sugarbush stands*

[For the determination of the number of trees per acre, average stand diameter, stocking, and spacing for sugarbush management]

| Dbh (inches) | Number of trees tallied | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 2 | 458 | 917 | 1375 | 1834 | 2292 | 2750 | 3209 | 3667 | 4125 | 4584 | 5042 | 5501 | 5959 | 6417 | 6876 |
| 4 | 115 | 229 | 344 | 458 | 573 | 688 | 802 | 917 | 1031 | 1146 | 1260 | 1375 | 1490 | 1604 | 1719 |
| 6 | /51 | ○102 | /153 | /204 | X255 | /306 | /357 | /407 | 458 | 509 | 560 | 611 | 662 | 713 | 764 |
| 8 | /29 | /57 | /86 | /115 | /143 | /172 | X201 | /229 | 258 | 287 | 315 | 344 | 372 | 401 | 430 |
| 10 | /18 | /37 | ○55 | /73 | /92 | /110 | 128 | 147 | 165 | 183 | 202 | 220 | 238 | 257 | 275 |
| 12 | /13 | /25 | /38 | 51 | 64 | 76 | 89 | 102 | 115 | 127 | 140 | 153 | 165 | 178 | 191 |
| 14 | 9 | 19 | 28 | 37 | 47 | 56 | 65 | 75 | 84 | 94 | 103 | 112 | | | |
| 16 | ○7 | /14 | 21 | 29 | 36 | 43 | 50 | 57 | 64 | 72 | 79 | 86 | | | |
| 18 | 6 | 11 | 17 | 23 | 28 | 34 | 40 | 45 | 51 | 57 | 62 | 68 | | | |
| 20 | 5 | 9 | 14 | 18 | 23 | 27 | 32 | 37 | 41 | | | | | | |
| 22 | 4 | 8 | 11 | 15 | 19 | 23 | 27 | 30 | 34 | | | | | | |
| 24 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 25 | 29 | | | | | | |
| 26 | 3 | 5 | 8 | 11 | 14 | 16 | 19 | 22 | 24 | | | | | | |
| 28 | 2 | 5 | 7 | 9 | 12 | 14 | 16 | 19 | 21 | | | | | | |
| 30 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | | | | | | |

*Tally Legend*

Maple

O [illegible]

X [illegible] species

*Number of plots*

• • = 4
• •

*No. of trees/acre*

[illegible] = [illegible]

*Total Number of Trees Per Acre.*—Add the last figures checked on each line and divide by the number of point samples tallied. 459 + 229 + 110 + 36 + 14 = 848 ÷ 4 = 212

*BA Per Acre.*—Add the total number of entries in each size class, multiply by 10 and divide by the number of point samples tallied. (BA factor = 10)

27 × 10 = 270 ÷ 4 = 68

STAND DESCRIPTION:

Number of trees per acre 212

BA per acre 68

Average stand dbh 7.5

Trees per acre at C level 140
(or level selected for management)

BA at C level 45
(or selected level)

STAND PRESCRIPTION:

Mark for cutting or girdling 69 trees = 23 BA
(Total minus C or selected level)

Average crop tree spacing [illegible] feet

forest
owners, and management of the National Forests
service

# Recommended Action for the Wood-flooring Industry to Secure Its Share of the Urban Rehabilitation Market

by Robert L. Nevel, Jr.

USDA FOREST SERVICE RESEARCH PAPER NE-287
1974

NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Author

ROBERT L. NEVEL, JR., received his bachelor of science degree in forest technology from The Pennsylvania State University in 1965 and his master of forestry degree in wood technology from Yale University in 1968. He joined the staff of the Northeastern Forest Experiment Station at the Forest Products Marketing Laboratory, Princeton, West Virginia, in 1968. At the time this report was prepared, he was in charge of construction-oriented research on secondary manufactured wood products at that laboratory.

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## ABSTRACT

Urban rehabilitation is a major market for wood flooring, but if wood flooring is to continue to be used to any great extent in urban rehabilitation, it must be made more acceptable to the building contractor and housing owner. Changes in distribution, supply, and pricing could make wood flooring more readily available; product modification could reduce its short-term costs; and other changes could make wood flooring more economical and compatible with present working methods.

URBAN REHABILITATION—the renovation of existing housing units or the construction of new housing units in their place—presents a large market for building products made of wood. One of the major products for this market is wood flooring.

From our investigation of the urban rehabilitation market,[1] we estimate the national market for flooring in rehabilitation projects to be about 1 billion square feet per year through 1980. Although no comprehensive data are available, we also found indications that the use of wood flooring in the rehabilitation of urban housing is decreasing even though urban rehabilitation continues to increase. This trend was especially noticeable in the Northeast, where wood flooring has always been the traditional residential floor surface.[2]

## WHAT DOES THE INDUSTRY NEED?

To secure its share of the urban rehabilitation market, the wood-flooring industry needs better information about the factors that influence flooring selection and the problems encountered in using wood flooring. More important, the industry needs to know what factors tend to restrict the use of wood flooring in urban rehabilitation and how to overcome them.

To determine what the problems are and to suggest possible solutions, we interviewed

[1]Boyer, James. Potential wood markets in urban rehabilitation (a literature review). Unpublished manuscript. USDA Forest Serv. Forest Prod. Market. Lab., Princeton, W. Va. 1966.

Nevel, Robert L., Jr. Factors affecting the use of hardwood flooring in urban rehabilitation. USDA Forest Serv. Res. Pap. NE-273. 12 p. NE Forest Exp. Sta., Upper Darby, Pa. 1973.

[2]Nevel, Robert L., Jr. Urban rehabilitation characteristics, methods, and requirements and their effect upon the use of hardwood flooring and other building materials (an intensive case study). Unpublished manuscript. USDA Forest Serv. Forest Prod. Market. Lab., Princeton, W. Va. 1972.

urban-rehabilitation officials, architects, housing owners, and building contractors in New Haven, Connecticut. An intensive evaluation of one city was preferred to a more extensive survey of several cities, and New Haven was judged to be representative of most cities actively involved in housing rehabilitation. The interviewees represented several profit-making and non-profit organizations involved in both public and private housing construction.

The results of the interviews were analyzed and evaluated along with other data and information collected from the literature, brief visits to other cities in the Northeast, and discussions with various other public and private wood-flooring and housing officials throughout the United States. Suggested areas of improvement were indicated largely by the interviewees and analyzed in light of the overall study results.[3]

## FACTORS IN FLOORING SELECTION

The interviews indicated that acceptance and use of a product in urban rehabilitation does not result entirely from its inherent or assumed economic and physical properties. Rather, many factors interact to affect the choice.

We found that the most important influences in the selection of flooring are the preferences of the building contractor and the housing owner. They are the ones most responsible for specifying flooring materials. They are concerned primarily with the availability, cost, and compatibility with their working methods of the flooring materials, and their effect on the approval, financing, and acceptance of their housing units.

Other factors such as product information, product image, and product use can be important influences; but they represent additional benefits or limitations rather than criteria for selecting a type of flooring.

Although wood flooring is probably used in 40 to 60 percent of the nation's urban rehabilitation, it is less preferred now by the builder and the owner than it was in the past. In New Haven alone, where wood floors predominate in both new and renovated units, interviewees estimated that this change in preference caused as much as a 20-percent drop in the use of wood flooring in the city's projects during the period 1965 to 1970. They consider wood flooring more expensive and more difficult to obtain, and more difficult and less expedient to install than vinyl asbestos tile, composition sheet, or carpet.

A better understanding of these factors will help the wood-flooring industry to initiate changes in manufacturing and marketing operations, which will enable it to continue supplying the market.

[3]More detailed information about the study may be obtained from the author.

## SUGGESTED ACTION TO INCREASE THE USE OF WOOD FLOORING

### Improve Availability

Unlike normal residential construction, urban rehabilitation tends to be non-cyclical. The housing owners and building contractors prefer products that are consistently and readily available on a year-round basis, and at relatively stable prices.

Indications are that wood flooring is not always readily obtainable. Of all the flooring products used in urban rehabilitation, the interviewees rated wood flooring products the lowest in availability. Most contractors disliked trying to get wood flooring because there are too many problems in getting it when they need it, getting prices, finding reliable suppliers, and finding large enough quantities or suitable varieties in stock to satisfy their needs. The interviewees commented frequently that they would like to see changes made in the distribution and marketing of wood flooring; and that if wood flooring cannot be had when and where it is needed, then other efforts to increase its use are of little consequence.

The distribution and supply of wood flooring products could be improved to make supply and prices fairly constant from season to season, regardless of market demand, fluctuations in the economy, and the cost and supply

of raw materials. More stress could be placed on the traditional methods of distribution so that regularly supplied wood flooring would be handled by more large suppliers on a more dependable basis.

The large building materials or flooring suppliers could be easily used to help eliminate wood flooring shortages that cause lost time and inconvenience for the contractor. Larger quantities and greater varieties could be distributed to these suppliers to meet local or regional demands more quickly and economically. Contracts could be negotiated with the builder or housing developer to fix prices and supply over a period of time. Greater stability in the supply and price of wood flooring could help to insure its year-round use by the urban rehabilitation market. Also, the producers that are close to the market could act as suppliers.

In addition, we found that the wood-flooring industry and those in association with it should strive to make themselves, as well as their product, more available to the contractors and others in urban rehabilitation responsible for specifying flooring. With some exceptions, the middlemen are inactive in gathering market information, and market reports on urban rehabilitation are limited in number and value to the flooring industry. Increased representation and more direct communication from suppliers and producers could help determine market demands and trends.

### Reduce Costs to the Consumer

The overall competitive position of wood flooring could be improved by reducing prices and installation costs, which require expenditures of money in the short run. The interviewees felt that wood floors generally compare well with non-wood floors in long-term cost, but that short-term costs are generally higher for wood flooring. Short-term costs are especially important to the contractor and owner, who are more concerned with initial costs and satisfactory service for the first few years. In the selection of flooring, initial costs usually override other costs, such as the cost of maintenance, that can be deferred, and long-term cost factors, such as wear life and frequency of replacement.

More efficient installation holds the greatest promise for improving the competitive position of wood flooring. The most critical need is for reducing the time and labor required to install wood floors. The interviewees felt that wood flooring—especially strip flooring—cannot compete with other materials in speed or cost of installation because of the need for skilled labor and the time required for finishing and drying.[4]

Thinner and larger sections of wood flooring—either block or strip flooring—could make wood flooring more competitive if the sections were panelized and prefinished in sizes that could be handled and installed readily by two men. Panels suggested by the interviewees frequently included some sort of laminated block, 4 by 8 feet by 3/8 inch.

Experiments by industry and government researchers with various types and thicknesses of panels have proven that thinner, panelized, and prefinished flooring can sharply reduce the time and cost of installing wood floors.[5] Researchers at the Forest Products Marketing Laboratory in Princeton, West Virginia, have estimated that 75 percent of the time required to install strip flooring can be saved by using conventional installation procedures, but working with 8-foot by 9-inch panels of standard-size strip flooring.

Produced modification in the form of thinner flooring also offers distinct possibilities for savings in material costs to the manufacturers, which could be passed on to the building contractor and housing owner. Generally, the long wear life and structural strength of conventional 25/32-inch-thick wood strip flooring are not needed in most urban rehabilitation. For years, factory-produced block flooring with a 5/16-inch wearing surface has provided

[4]It takes two to three times as long to complete the installation of most wood flooring products as to install carpeting or resilient flooring.

[5]U.S. Forest Products Laboratory. Wood floors for dwellings. U.S. Dep. Agr. Handb. 204, 44 p., 1961.

Micklewright, James T. A problem analysis of hardwood flooring markets. Unpublished manuscript. USDA Forest Serv. Forest Prod. Market. Lab., Princeton, W. Va. 1964.

Smith, Walton R., Frank Longwood, and L. O. Anderson. Urban rehabilitation—a challenge to wood products. (Unpublished report of the Forest Service Task Force on Urban Rehabilitation). USDA Forest Serv. SE. Forest Exp. Sta., Asheville, N.C., 156 p. 1966.

satisfactory wear life and serviceability for floor surfaces in all types of housing.

Furthermore, the industry could manufacture and market more lower grade wood flooring to help reduce wood flooring costs to the contractor and housing owner. For all practical purposes, the lower grades of wood flooring differ from the higher grades only in appearance and price.

Wood flooring could also be made more economically attractive through the elimination of difficulties and inconveniences that the builders and the owner frequently encounter with the use of conventional wood flooring. The interviewees indicated that protection from moisture is often a problem; and that better methods of keeping wood flooring dry and dimensionally stable in storage, enroute to the site, and on the job would reduce costs and difficulty.

They also mentioned frequently that the finishes and the ease and cost of finishing need attention, as do problems associated with repair, replacement, and maintenance of wood flooring. Wood flooring and its finishes are considered more susceptible to noticeable damage than competitive materials; and damaged wood flooring is more difficult and expensive to repair. The industry could economically alleviate some of these problems and associated expenses by producing and marketing prefinished flooring, in the relatively inexpensive distressed finish.

### Improve Product Compatibility

The contractors felt that wood flooring could be made more attractive by making it usable with less interruption of work flow. We found that, particularly in renovation, wood flooring is generally installed over a subfloor before interior partitions are erected or finish wall materials applied. Unless prefinished flooring is used, the need for finishing and drying makes carpeting and resilient flooring preferable because workers need not return later to complete operations. In addition, carpeting and the resilients can be installed closer to the end of the construction job and with less-skilled labor.

With known technology, wood flooring products could be manufactured to meet preferred construction practices as well as market demands. Several types have been recommended, manufactured, and tested; some have been put to satisfactory use and others represent good possibilities.[5]

### Improve Promotion and Advertising and Present Additional Benefits

Although not considered nearly as important as product availability, costs, and compatibility, some other factors were mentioned in the interviews that affect the acceptance and selection of flooring products.

Wood flooring could be made more appealing by emphasizing the additional benefits it provides. The interviews indicated that the techniques employed in promotion and advertising create the users' image of a product; that wood flooring is not well promoted; and that its characteristics and properties need to be presented more frequently and in a way that informs the user of its inherent beauty, variability, adaptability, and freedom of maintenance.

Then there is aesthetic appeal: the feeling of luxury, prestige, and modernity. Wood flooring was seldom thought of in these terms.

The wood-flooring industry could improve the image and acceptance of wood flooring by employing more appeals to the senses, more competitive sales arguments, more glamorous advertising, and more point-of-purchase advertising; and by providing more technical information and assistance. Much of this could be accomplished at the source of supply and through trade associations.

Other changes that could help promote the use of wood flooring products are improvements in color and design, versatility, the ability to blend with decor and furnishings, shock and sound absorbency, and resistance to grease, solvents, toys, and children.

## DISCUSSION

Wood flooring has traditionally been used to a greater extent in the rehabilitation of urban housing than any other type of flooring. This trend cannot be expected to continue unless certain measures are taken by the wood-flooring industry to make wood floor-

ing more acceptable to the building contractor and housing owner.

A well-rounded marketing program is essential to make wood flooring more desirable and more readily obtainable. The industry should attempt to integrate in a forward direction to optimize functional performance and to control the marketing and distribution of its manufactured products to the ultimate consumer.

Although marketing endeavors, particularly those affecting product availability, need priority attention, improvement in these areas probably will not help sell wood flooring to the urban rehabilitation market unless the industry also provides better, more compatible products to the market. Product modification for more efficient installation is the best opportunity for the industry to have a major share of the market.

All the recommended improvements could be accomplished with known methods and technology. However, most of the changes will not be easy, and traditional methods and products may have to be eliminated. Our data indicate that, in addition to insuring itself of a good market in urban rehabilitation, the wood-flooring industry could benefit from these efforts in other residential markets.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

By Stanford L. Arner

# PROFILE

## A computer program for displaying the geometric relationships of the responses in a factorial design

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NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## The Author

STANFORD L. ARNER has served as a computer programmer and mathematical statistician in the biometrics branch of the Northeastern Forest Experiment Station since 1966. He received a Bachelor of Science degree in Forest Science from the Pennsylvania State University in 1966 and a Master of Science degree from the School of Forest Resources at the Pennsylvania State University in 1971.

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# PROFILE

## A computer program for displaying the geometric relationships of the responses in a factorial design


### ABSTRACT

One procedure in analyzing the responses to factors in an experiment is to construct profiles of the means. Profiles are plots of the sample means of each level of one factor at each level of one or more of the other factors in the experiment. The construction of these profiles and tests of hypotheses about the mean responses is called profile analysis. This paper discusses profile analysis and presents a computer program which produces profiles of the experimental means.

ONE OBJECTIVE of designed experiments is to find the relationship of the response to various factors in the experiment. Profile analysis is a technique for studying the geometric relationships among the expected responses in a multifactor experiment. Profiles are line segments connecting the means for the levels of one factor (A) at each level of a second factor (B). If there is a third factor (C), there are three possible simple profiles: the AB profiles at each level of C; the AC profiles at each level of B; and the BC profiles at each level of A. Also, there are the two factor profiles combined over all levels of the third factor, and the one factor profiles combined over all levels of the other two factors.

To introduce profile analysis, an example of a three-way factorial experiment is presented. In this hypothetical experiment the height growth of two species of trees fertilized with two levels of nitrogen and three levels of phosphorus is measured. Let $Y_{ijkm}$ be the height growth on the $m^{th}$ tree of the $i^{th}$ species (factor A), fertilized with the $j^{th}$ level of nitrogen (factor B) and the $k^{th}$ level of phosphorus

(factor C). The mean height growth of the $M_{ijk}$ trees in the $ijk^{th}$ factor combination is

$$\bar{Y}_{ijk} = \sum_{m=1}^{M_{ijk}} Y_{ijkm}/M_{ijk}.$$

Experimental values for the $\bar{Y}_{ijk}$ are presented in table 1. For demonstration purposes

Table 1.—*Means for simple profiles*

| | $A_1$ | | | $A_2$ | | |
|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_1$ | $C_2$ | $C_3$ |
| $B_1$ | 40 | 30 | 60 | 20 | 10 | 40 |
| $B_2$ | 60 | 50 | 20 | 40 | 30 | 0 |

we assume that these are population values. With real data the values obtained would be sample means rather than population means. The expected value of the sample means would be the population means; that is,

$$E(\bar{Y}_{ijk}) = \mu_{ijk}.$$

The simple profiles of interest might be the nitrogen by phosphorus profiles for each species. One of the nutrient factors (say phosphorus) is chosen for the horizontal axis, the other (nitrogen) is chosen for the vertical axis. The 3 levels of phosphorus are then the points along the horizontal axis at which the mean responses $\bar{Y}_{ijk}$ are plotted for each level of nitrogen. Using the values in table 1, $\bar{Y}_{111}$ would be positioned at a height of 40 on the vertical axis directly above the first index point of the horizontal axis; $\bar{Y}_{121}$ would be directly above the first point at 60 on the vertical axis. The simple profiles for species 1 are the first set of profiles in figure 1, while those for species 2 are the second set.

The means for the two-way profiles combined over the third factor are:

$$\bar{Y}_{.jk} = \sum_{i=1}^{2} \bar{Y}_{ijk}/2$$

$$\bar{Y}_{i.k} = \sum_{j=1}^{2} \bar{Y}_{ijk}/2$$

$$\bar{Y}_{ij.} = \sum_{k=1}^{3} \bar{Y}_{ijk}/3$$

For example:

$$\bar{Y}_{.11} = (\bar{Y}_{111} + \bar{Y}_{211})/2 = (40 + 20)/2 = 30$$

Figure 1.—Simple BC profiles for each level of factor A.

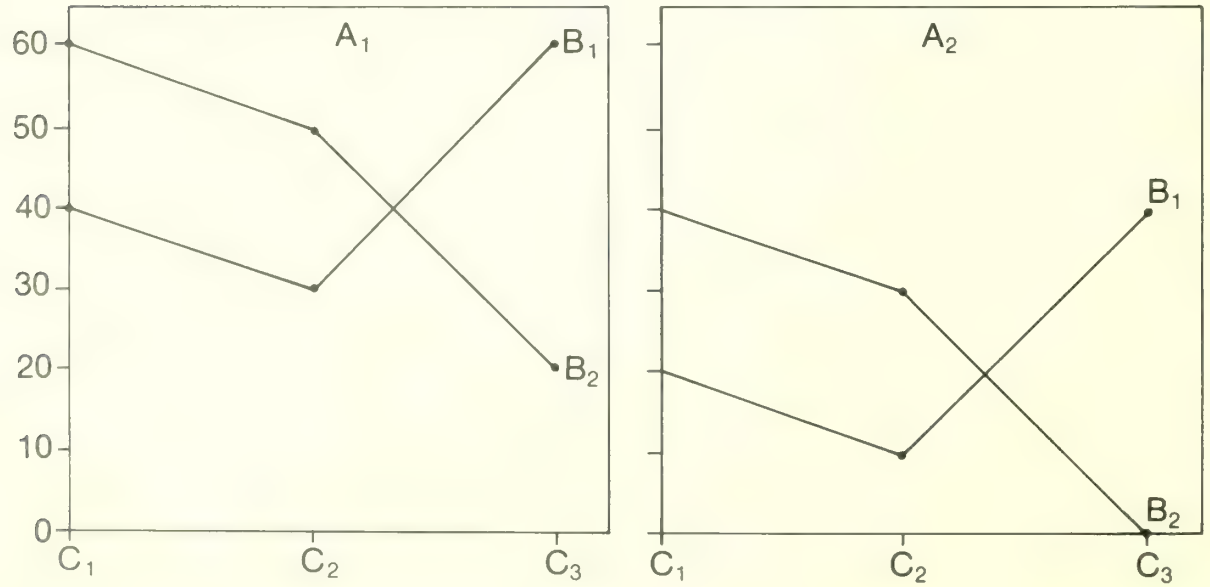
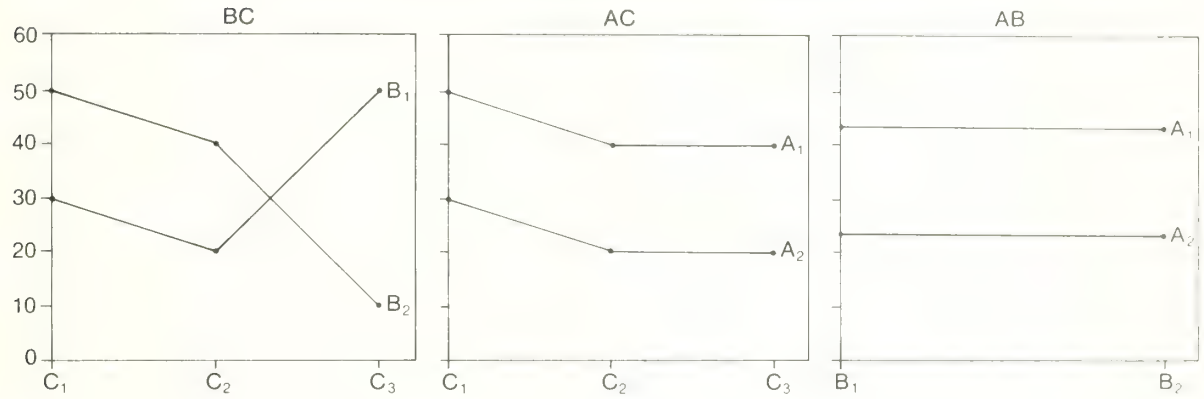


Table 2.—*Means for two-way profiles combined over third factor*

| | $A_1 + A_2$ | | | | $B_1 + B_2$ | | | | $C_1 + C_2 + C_3$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | | $C_1$ | $C_2$ | $C_3$ | | $A_1$ | $A_2$ |
| $B_1$ | 30 | 20 | 50 | $A_1$ | 50 | 40 | 40 | $B_1$ | 43.33 | 23.33 |
| $B_2$ | 50 | 40 | 10 | $A_2$ | 30 | 20 | 20 | $B_2$ | 43.33 | 23.33 |

Figure 2.—Two-way profiles combined over third factor.




The values of the means combined over the third factor are given in table 2, and the combined profiles are given in figure 2.

The last sets of profiles are based on the means combined over two factors. These are:

$$\overline{Y}_{..k} = \sum_{j=1}^{2} \overline{Y}_{.jk}/2 = \sum_{i=1}^{2} \overline{Y}_{i.k}/2$$

$$\overline{Y}_{.j.} = \sum_{i=1}^{2} \overline{Y}_{ij.}/2 = \sum_{k=1}^{3} \overline{Y}_{.jk}/3$$

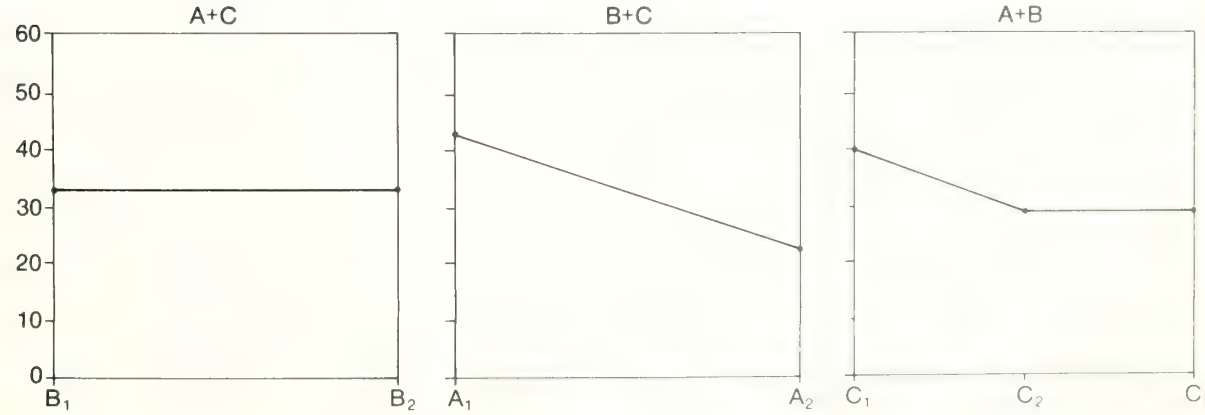
$$\overline{Y}_{i..} = \sum_{j=1}^{2} \overline{Y}_{ij.}/2 = \sum_{k=1}^{3} \overline{Y}_{i.k}/3$$

The values of the means combined over two factors are given in table 3 and the combined profiles are shown in figure 3.

Table 3.—*Means for single factors combined over other two factors*

| | | | | | |
|---|---|---|---|---|---|
| $B_1$ | 33.33 | $A_1$ | 43.33 | $C_1$ | 40 |
| $B_2$ | 33.33 | $A_2$ | 23.33 | $C_2$ | 30 |
| | | | | $C_3$ | 30 |

Figure 3.—Profiles on one factor combined over other two factors.



## Profile Analysis And The Factorial Model

The statistical model for a three way factorial design can be written

$$\mu_{ijk} = \mu + A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk} + ABC_{ijk};$$

further

$$\Sigma_i A_i = \Sigma_j B_j = \Sigma_k C_k = 0$$

$$\Sigma_i AB_{ij} = \Sigma_j AB_{ij} = \Sigma_i AC_{ik} = \Sigma_k AC_{ik} = \Sigma_j BC_{jk} = \Sigma_k BC_{jk} = 0$$

$$\Sigma_i ABC_{ijk} = \Sigma_j ABC_{ijk} = \Sigma_k ABC_{ijk} = 0;$$

The parameters are the main effects A, B, C; the two-way interactions AB, AC, BC; and the three-way interaction ABC.

For interpretation of the two-way interactions we look at the two-way profiles combined over the levels of the third factor. For example, the means combined over factor A are

$$\mu_{.jk} = \sum_{i=1}^{I} \mu_{ijk} / I$$

$$= ( I\,\mu + \Sigma A_i + I B_j + I C_k + \Sigma AB_{ij} + \Sigma AC_{ik} + I BC_{jk} + \Sigma ABC_{ijk} ) / I$$

$$= \mu + B_j + C_k + BC_{jk},$$

since the restrictions imposed on the parameters result in all terms involving A summing to zero.

The $\mu_{.jk}$'s are the means plotted on the combined BC profiles which are used to determine if there is a BC interaction. The interaction is the degree to which the profiles are not parallel. If the profiles are parallel there is no interaction.

The BC interaction can be expressed in terms of $\mu_{.jk}$. If there is no BC interaction the distance between profiles is the same at each point along the horizontal axis. Therefore $\mu_{.1k} - \mu_{.2k}$ is constant for all k. For this example the hypothesis of no BC interaction is:

$$(\mu_{.11} - \mu_{.21}) - (\mu_{.12} - \mu_{.22}) = 0$$

$$(\mu_{.12} - \mu_{.22}) - (\mu_{.13} - \mu_{.23}) = 0$$

These linear combinations of means are functions of the BC interactions only since

$$\mu_{.11} - \mu_{.21} - \mu_{.12} + \mu_{.22}$$

$$= (\mu + B_1 + C_1 + BC_{11}) - (\mu + B_2 + C_1 + BC_{21})$$

$$- (\mu + B_1 + C_2 + BC_{12}) + (\mu + B_2 + C_2 + BC_{22})$$

$$= BC_{11} - BC_{21} - BC_{12} + BC_{22}.$$

Likewise,

$$\mu_{.12} - \mu_{.22} - \mu_{.13} + \mu_{.23} = BC_{12} - BC_{22} - BC_{13} + BC_{23}.$$

For this example (table 2),

$$(\mu_{.11} - \mu_{.21}) - (\mu_{.12} - \mu_{.22}) = (30\text{-}50) - (20\text{-}40) = 0$$

$$(\mu_{.12} - \mu_{.22}) - (\mu_{.13} - \mu_{.23}) = (20\text{-}40) - (50\text{-}10) = -60$$

implying that the BC interaction is not zero. The BC profiles (fig. 2), show that the profile segments between $C_1$ and $C_2$ are parallel and the segments $C_2$ and $C_3$ are not parallel.

The combined AB and AC profiles provide similar information about the AB and AC interactions. In the example, both the AB and AC profiles are parallel. Therefore there is no AB or AC interaction. The interactions associated with the combined profiles are called the overall interaction effects.

Now consider the simple BC profiles for one level of A, (fig. 1). The profiles are not parallel; that is, the BC interaction at $a_1$ and $a_2$ is not zero. These interactions are called simple interaction effects (denoted BC for $a_i$).

When each cell of the experiment has the same number of observations, the variation in the simple interactions is related to the variation in the overall interactions as follows:

$$SS_{BC \text{ at } a_1} + SS_{BC \text{ at } a_2} = SS_{BC} + SS_{ABC}.$$

In the example the variations due to the simple BC interactions are both positive, therefore one or both of $SS_{BC}$ and $SS_{ABC}$ are positive. We have seen that $SS_{BC}$ is not zero. But what is the value of $SS_{ABC}$?

For information about the variation due to the overall ABC interactions, we compare the

simple BC profiles. The three-way interaction is zero when the BC interactions for each level of A are similar. This could occur either when the simple profiles are parallel to each other or when both simple interactions are zero. For our data, the individual simple profiles are not parallel, but the sets are parallel to each other. Therefore the ABC interaction is zero.

In terms of means, the hypothesis of no three-way interaction is,

$$\begin{bmatrix} (\mu_{111}-\mu_{121}) - (\mu_{112}-\mu_{122}) = \\ (\mu_{211}-\mu_{221}) - (\mu_{212}-\mu_{222}) \\ \\ (\mu_{112}-\mu_{122}) - (\mu_{113}-\mu_{123}) = \\ (\mu_{212}-\mu_{222}) - (\mu_{213}-\mu_{223}) \end{bmatrix}$$

or,

$$\begin{bmatrix} ((\mu_{111}-\mu_{121}) - (\mu_{112}-\mu_{122})) - \\ ((\mu_{211}-\mu_{221}) - (\mu_{212}-\mu_{222})) = 0 \\ \\ ((\mu_{112}-\mu_{122}) - (\mu_{113}-\mu_{123})) - \\ ((\mu_{212}-\mu_{222}) - (\mu_{213}-\mu_{223})) = 0. \end{bmatrix}$$

For our example the values for the hypothesis are,

$$\begin{bmatrix} ((40 - 60) - (30 - 50)) - \\ ((20 - 40) - (10 - 30)) = 0 \\ \\ ((30 - 50) - (60 - 20)) - \\ ((10 - 30) - (40 - 0)) = 0 \end{bmatrix}$$

The hypothesis of no three-way interaction is a function of the ABC interaction only and can be expressed in these terms by substituting $ABC_{ijk}$ for $\mu_{ijk}$.

The interpretation of mean profiles can be extended to experiments with more than three factors. For instance, the four-way profiles could be created by plotting the two factor profiles at each combination of levels of the other two factors. Interpretation of parameters and tests of the statistical model for experiments involving more than three factors is difficult, however.

Table 4 summarizes the relationships that the sums of squares for the two-way and three-way interactions have with the form of the simple and combined two-way profiles. As an example, suppose the test results given in the last line of table 4 are encountered. If the lines of the AB profile combined over factor C are parallel and the lines in each simple AB profile are parallel, even though the simple profiles are not parallel to each other, both $SS_{AB}$ and $SS_{ABC}$ are zero.

Table 4.—*Relationship of simple and combined profiles to the variation due to two- and three-way interactions*

| Lines in combined profile | Lines in one simple profile compared to lines in all other simple profiles | Lines in each simple profile | Value of $SS_{AB}$ | Value of $SS_{ABC}$ |
|---|---|---|---|---|
| NP | NP | NP | >0 | >0 |
| NP | P | NP | >0 | 0 |
| P | NP | NP | 0 | >0 |
| P | P | P | 0 | 0 |
| P | NP | P | 0 | 0 |

NP = The profiles are not parallel.
P = The profiles are parallel.

For a more detailed discussion of profile analysis, see Winer 1962, pp. 162-184.

## DESCRIPTION OF THE COMPUTER PROGRAM—PROFILE

Program *Profile* is designed to show the relationships between the response and various factors in the experiment.

Any pair of factors can be chosen for the vertical or the horizontal axis. Further, a third factor can be designated such that profiles will be created for each level of this third factor. Also, specific levels of any of the factors can be selected so that a set of profiles is plotted for the one level only. If there are multiple observations for each level of the factors — for example, measurements on a variable at different time periods—the response vector can be designed as a factor using the different observations as the levels.

The scale for the levels of the factor on the horizontal axis can have unequal distances between levels. If the time periods are 1, 2, and 4, for example, the distance between levels 2 and 3 is twice the distance between levels 1 and 2.

The responses can be transformed by in-

sertion of a user-written FORTRAN subroutine.

The program is designed to handle data from multiple factor experiments. If there is a subclass for which no record is observed, then that cell is considered missing from the design. A missing cell is ignored in the calculation of a combined mean. Therefore the profile of the combined means must be interpreted with caution.

There is an option that is useful when the response variables are counts. In this case the absence of records implies a zero count for that cell. The cell is not considered missing from the design, and is therefore included in the calculation of a combined mean. If the design is incomplete, the missing cells can be identified by the user.

The differences between the two methods can best be illustrated by the calculation of cell means. Suppose there are two factors, each with two levels. If there is at least one observation in each cell the means are calculated as follows:

| Normal Procedure | Counts Option |
|---|---|
| $\overline{Z}_{ij} = Z_{ij}/n_{ij}$ | $\overline{Z}_{ij} = Z_{ij}/1$ |
| $\overline{Z}_{i.} = (\overline{Z}_{i1} + \overline{Z}_{i2})/2$ | $\overline{Z}_{i.} = (Z_{i1} + Z_{i2})/2$ |

If there is no record for $Z_{12}$ and $Z_{12}$ is not designed as missing for the counts option;

| | |
|---|---|
| $\overline{Z}_{1.} = \overline{Z}_{11}/1$ | $\overline{Z}_{1.} = (Z_{11} + 0)/2$ |
| $\overline{Z}_{2.} = (\overline{Z}_{21} + \overline{Z}_{22})/2$ | $Z_{2.} = (Z_{21} + Z_{22})/2$ |

### Program Control Cards

1. *Data Set Control Card*

*Column*

1, 2 NS = Number of factors in design.

3, 4 NYR = Number of responses per observation (length of response vector).

5, 6 NF = Number of format cards ($\leq 3$).

7, 8 NFL = Input file number (5 is default).

9, 10 PM If PM=0 print all cell means of complete design.
If PM=1, skip.

11, 12 NT If NT = 0 no data transformation.
If NT = 1 transform data with user-written subroutine.

13, 14 ICNT If ICNT = 0 responses are measurements on some continuous variable.
If ICNT = 1 responses are frequency counts.

15, 16 NDES = Number of cells not included in design. (If ICNT=1 and some of the factor combinations are not included in the design of the experiment NDES is the number of cards to be read containing the factor levels for which the observation count is set to zero.)

21-25 LEVELS (1) = Number of levels of response factor after transformation.

26-75 LEVELS (L) = Number of levels of factor L; (L = 1 to NS). These are consecutive fields of length 5.

2. *Variable Format Cards*

These begin with a left parenthesis in column 1 of the first card which is followed by NS I format designations and NYR F or E format designations. A right parenthesis should follow the last F or E format field.

3. *Missing Cell Cards* (Optional)

One card for each missing criterion and/or cell in the design. The first 2 digit code designates the element of the response vector and the remaining 2 digit codes represent the factor levels of the missing values; card format (11 I2). Missing cell cards are needed when ICNT = 1 and NDES $\neq$ 0.

4. *Data Cards*

The data card format must conform to the variable format specifications. There are NS integers indicating the levels of the factors, followed by the response vector of length NYR. The factor level codes must be consecutive in-

tegers beginning with 1. If the codes are not consecutive integers a user transformation subroutine (TRANS) can be written to put the codes in the proper form. The response vector can also be transformed by this subroutine. If the data is on cards and if N is the number of cards per observation, N blank cards must follow last data card.

5. *Axis Title Card*
   *Cols.*
   1-28 YAXIS—Title for profile lines.
   29-56 XAXIS—Title for factor on horizontal axis.
   57-80 REPEAT—Title for factor given control value 116 on card 7.

6. *General Title*
   *Cols.*
   1-79 Title—general title for profile
   80 0 or blank = further plots involving present data follow
   1 = last plot for this data set (needed only if further data sets follow).

7. *Factor Control Card*

On this card the user specifies the profiles he wants plotted by assigning plotting codes to the factors in the experiment. One of the codes that appear below must be assigned to the response and one to each factor to indicate how each is used for the profiles.

The plotting codes are

I = Profiles for $I^{th}$ level of factor (or response).

113 = Profiles combined over levels of factor (or response).

114 = This factor (or response) used for vertical axis.

115 = This factor (or response) used for horizontal axis.

116 = Separate profiles plotted for each level of this factor (or response).

Codes 114, 115, and 116 can appear only once for each set of profiles. The NS+1 codes must be punched on the card in the following format. The remaining fields must be blank.

*Cols.*
1-5 Plotting Code for response vector.
6-10 Plotting Code for factor 1.
11-15 Plotting Code for factor 2.
. . . . . .
. . . . . .
. . . . . .
56-60 Plotting Code for factor 10.
80 NES — horizontal scale indicator
NES = 0 horizontal scale equally spaced.
= 1 horizontal scale unequally spaced; scale card follows:

8. *Horizontal Scale Card* (optional, needed only if column 80 of card 7 is 1)
   *Cols.*
   1-5 Scale position for level 1
   6-10 Scale position for level 2
as many fields of 5 as needed.

Repeat cards 5, 6, 7, and 8 if needed for each additional set of profiles. Repeat cards 1 to 8 for each additional data set.

## DATA TRANSFORMATION ROUTINE

The option for the user to transform the data with a FORTRAN subroutine is provided. The placement of the routine depends upon the system that is being used. The IBM 360 or 370 series requires that this routine immediately precede the object deck.

Suppose in the example the three levels of phosphorus (factor C) are coded 0, 2, and 5. These codes need to be changed to 1, 2, and 3 respectively. Suppose also that the user wants to examine the response on the square root scale. The transformation routine could be,

```
      SUBROUTINE TRANS (Y, I, N, DS)
      REAL Y(N)
      INTEGER DS, I(11)
      Y(2) = SQRT (Y(1))
      IF (I(4)-2) 1, 2, 3
    1 I(4) =1
      GO TO 4
    2 I(4) = 2
      GO TO 4
    3 I(4) = 3
    4 RETURN
      END
```

All arguments of the subroutine are trans-

ferred from the calling routine and are not specified by the user. The arguments N and DS should be explained further. N is the length of the response vector, DS is the number of the data set that is being read. If a job contains more than one data set for which different transformations are required, an IF statement must be inserted directing program flow to the appropriate transformations for each data set.

Notice that although the levels of the third factor are being recoded, the subscript for I is 4. If the $j^{th}$ factor is being recoded the subscript of I must be j + 1. This is necessary since the response is considered the first factor by the program.

## PROGRAMMING CONSIDERATIONS

Definitions:

1. NS = Number of factors.
2. MAX(j + 1) = Highest level of $j^{th}$ factor.
   MAX(1) = Length of response vector.
3. $MXSTR = \prod_{j=1}^{NS+1} MAX(j)$
4. NF = Number of format cards.
5. JMAX = Difference between largest and smallest relative levels of horizontal axis factor.

Restrictions:

1. NS $<$ 10
2. MAX(j) $\leq$ 99 all factors not used on vertical axis.
   $\leq$ 12 any factors used on vertical axis.
3. NF $<$ 3
4. 1 $<$ JMAX $<$ 110
4. MXSTR $<$ 5000

If a problem is encountered where MXSTR $>$ 5000 the following changes should be made in the main program:

1. Set MSTR = MXSTR.
2. Change dimension of Y and IC to Y (MXSTR) and IC (MXSTR).

## DESCRIPTION OF OUTPUT

Information from the first control card is printed on the first page of output. Following this is the variable format for this data set and a listing of the factor means.

For each job concerning this data set the actual profiles are preceded by a page containing means to be used on the profiles and the control values for each factor.

A profile for each level of the factor or response selected for the vertical axis is then plotted at each level of the horizontal axis. Numbers or letters are used as plotting characters to represent the levels of the vertical axis factor; levels 1 to 9 are represented by the integers 1 to 9, level 10 by 0, level 11 by A, and level 12 by B. A line segment consisting of the appropriate plotting character joins each point along the horizontal axis.

Overplots occur if the mean values of two or more profiles at any point on the horizontal axis are the same. These are listed on the page following the profiles in the form Z(I,J) = M, where I is the level of the vertical axis, J is the point on the horizontal axis, and M is the mean value.

## SAMPLE PROBLEM

The sample problem involves the same factors as discussed. The response vector is seedling height growth measured 1, 2, 4, and 8 years after application of the fertilizer. The data cards have a 1 punched in the field for the first factor. This dummy factor is included in order that a profile for any one of the factors alone can be plotted.

The first set of profiles uses the dummy factor for the vertical axis and plots the profiles for phosphorus at time 1, summing over the other factors. The second set of profiles plots the means for the two levels of N (1 = N present, 2 = N absent) for each level of phosphorus at time 1, while the third and fourth profiles represent the nitrogen by phosphorus profiles for each species.

Profile 1 shows that the mean height growth for the trees treated with the 3rd level of phosphorus is greater than the growth of the trees treated with levels 1 and 2. Profile 2 demonstrates the nitrogen by phosphorus in-

teraction. The mean height growth for phosphorus levels 2 and 3 is greater when nitrogen is present, while the mean growth for phosphorus level 1 is greater when nitrogen is absent.

Profiles 3 and 4 illustrate the lack of three-way interaction. The nitrogen by phosphorus profiles for each species are parallel to each other. Finally, profile 5 demonstrates the use of an additional control card to read relative values of the horizontal axis. The heights were measured at times 1, 2, 4, and 8. Therefore the horizontal axis distance between measurements 2 and 3 is twice the distance between times 1 and 2. This set of profiles also shows the increase in mean height growth with time, and the fact that the species 2 means are greater than the means of species 1 for each time period. Also, the difference is of the same magnitude in each time period.

## Literature Cited

Winer, B. J.
1962. STATISTICAL PRINCIPLES IN EXPERIMENTAL DESIGN. New York: McGraw Hill.

## ACKNOWLEDGMENT

The author wishes to thank Dr. Donald Seegrist, Biological Statistician at the Northeastern Forest Experiment Station for his encouragement and suggestions for improvement during the development of the program.

## CONTROL DECK FOR SAMPLE PROBLEM

```
 4 4 1 5 0 0 0 0        4    1    2    2    3
(4I2,7X,4F5.0)
 1 1 1 1              0    5   10   20
 1 1 1 2             32   37   42   52
 1 1 1 2             28   33   38   48
 1 1 1 3             60   65   70   80
 1 1 2 1             40   45   50   60
 1 1 2 2              9   14   19   29
 1 1 2 2             11   16   21   31
 1 1 2 3             40   45   50   60
 1 2 1 1             20   25   30   40
 1 2 1 2             45   50   55   65
 1 2 1 2             55   60   65   75
 1 2 1 3             80   85   90  100
 1 2 2 1             60   65   70   80
 1 2 2 2             32   37   42   52
 1 2 2 2             28   33   38   48
 1 2 2 3             60   65   70   80

DUMMY                          PHOSPHORUS
PROFILE TEST DATA     PHOSPHORUS MAIN  EFFECT   TIME 1
    1  114  113  113  115
NITROGEN                       PHOSPHORUS
NITROGEN X PHOSPHORUS    COMBINED SPECIES   TIME 1
    1    1  113  114  115
NITROGEN                       PHOSPHORUS                                  SPECIES
NITROGEN X PHOSPHORUS   EACH SPECIES        TIME 1
    1    1  116  114  115
SPECIES                        TIME PERIOD
SPECIES X TIME       LEVELS OF N AND P COMBINED
  115    1  114  113  113                                                        1
    1    2    4    8
```

Arner, Stanford L.
1974. **Profile—A computer program for displaying the geometric relationships of the responses in a factorial design.** NE. Forest Exp. Sta., Upper Darby, Pa.
21 p., illus. (USDA Forest Serv. Res. Paper NE-288)

Profiles are plots of the sample means of each level of one factor at each level of one or more of the other factors in an experiment. This paper presents a computer program which produces profiles of the experimental means and discusses the interpretation of these profiles.

U 681.3--015.5

U 681.3--015.5

Arner, Stanford L.
1974. Profile—A computer program for displaying the geometric relationships of the responses in a factorial design. NE. Forest Exp. Sta., Upper Darby, Pa.
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U 681.3--015.5

# OUTPUT FOR SAMPLE PROBLEM

```
PROFILE ANALYSIS, CONTROL INFORMATION FOR THIS DATA SET

NO. SUBSCRIPTS(FACTORS) =          4
NO. Y'S READ IN =                  4
NO. FORMAT CARDS =                 1
PRINT MEANS =                      0
DATA FILE NO. =                    5
COUNT OPTION, ICNT =               0

NO. CELLS NOT INCLUDED IN DESIGN FOR COUNT OPTION, NDES=     0

MAXIMUM VALUE OF EACH SUBSCRIPT,  FIRST SUBSCRIPT REFERS TO LENGTH OF Y VECTOR ON DATA CARD
    KK(L) =    4   1   2   2   3   1   1   1   1   1   1

FORMAT OF DATA
(4I2,7X,4F5.0)

TOTAL NO. OF RECORDS ON DATA SET =      16

FACTOR SUBSCRIPTS, FIRST IS NO. OF LEVELS OF OBSERVATION VECTOR

 4 1 1 1 1 1 1 1 1 1 1
                        Y1 -Y12  MEAN     0.0      5.00    10.00    20.00
                                 NOBS       1         1        1        1
 4 1 2 1 1 1 1 1 1 1 1
                        Y1 -Y12  MEAN    20.00    25.00    30.00    40.00
                                 NOBS       1         1        1        1
 4 1 1 2 1 1 1 1 1 1 1
                        Y1 -Y12  MEAN    40.00    45.00    50.00    60.00
                                 NOBS       1         1        1        1
 4 1 2 2 1 1 1 1 1 1 1
                        Y1 -Y12  MEAN    60.00    65.00    70.00    80.00
                                 NOBS       1         1        1        1
 4 1 1 1 2 1 1 1 1 1 1
                        Y1 -Y12  MEAN    30.00    35.00    40.00    50.00
                                 NOBS       2         2        2        2
 4 1 2 1 2 1 1 1 1 1 1
                        Y1 -Y12  MEAN    50.00    55.00    60.00    70.00
                                 NOBS       2         2        2        2
 4 1 1 2 2 1 1 1 1 1 1
                        Y1 -Y12  MEAN    10.00    15.00    20.00    30.00
                                 NOBS       2         2        2        2
 4 1 2 2 2 1 1 1 1 1 1
                        Y1 -Y12  MEAN    30.00    35.00    40.00    50.00
                                 NOBS       2         2        2        2
 4 1 1 1 3 1 1 1 1 1 1
                        Y1 -Y12  MEAN    60.00    65.00    70.00    80.00
                                 NOBS       1         1        1        1
 4 1 2 1 3 1 1 1 1 1 1
                        Y1 -Y12  MEAN    80.00    85.00    90.00   100.00
                                 NOBS       1         1        1        1
 4 1 1 2 3 1 1 1 1 1 1
                        Y1 -Y12  MEAN    40.00    45.00    50.00    60.00
                                 NOBS       1         1        1        1
 4 1 2 2 3 1 1 1 1 1 1
                        Y1 -Y12  MEAN    60.00    65.00    70.00    80.00
                                 NOBS       1         1        1        1
```

PROFILE ANALYSIS, MEANS OF PROFILE CELL PLOTS FOR JOB 1

FACTOR LEVELS

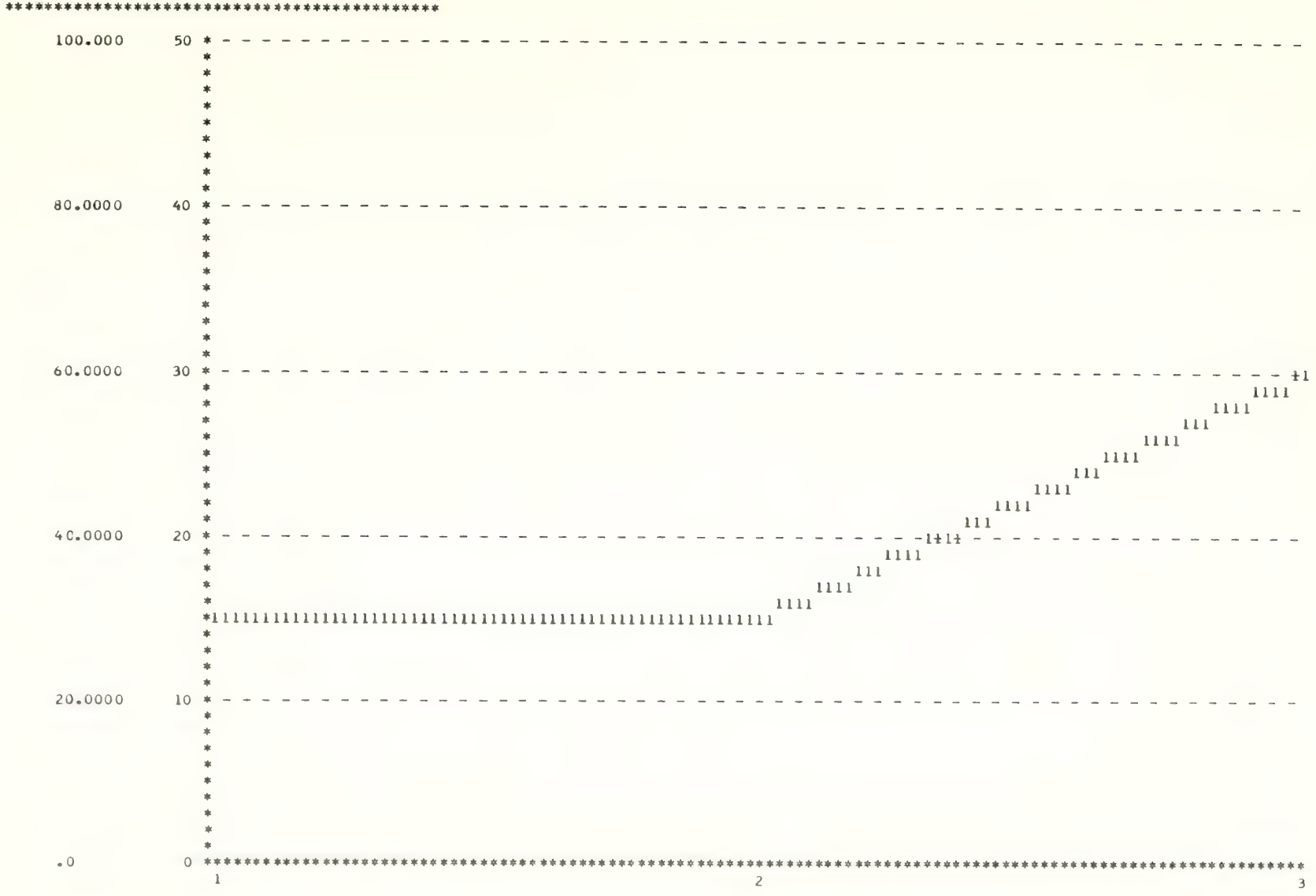
0 INDICATES THE LEVELS OF THIS FACTOR ARE TO BE THE LEVELS OF THE X AXIS
* INDICATES THE FACTOR FOR WHICH A SEPARATE PROFILE PLOT IS PRODUCED FOR EACH OF ITS LEVELS.
X INDICATES FACTOR FOR HORIZONTAL AXIS.
Y INDICATES FACTOR FOR VERTICAL AXIS

LEVELS OF X AXIS

| | | | 1 | 2 | 3 |
|---|---|---|---|---|---|
| Y | X | | | | |
| 1 1 1 1 0 1 1 1 1 1 1 | | | | | |
| | Y1 -Y12 | MEAN | 30.00 | 30.00 | 60.00 |
| | | NOBS | 4 | 4 | 4 |

CONTROL VALUES FOR FACTOR SUBSCRIPTS
113 IMPLIES CELL MEANS ARE SUMMED OVER THIS SUBSCRIPT.
114 LEVELS OF Y AXIS.
115 LEVELS OF X AXIS.
116 PRODUCE A SEPARATE PROFILE PLOT FOR EACH LEVEL OF THIS SUBSCRIPT
1-111 THIS LEVEL OF LTH FACTOR IS TO BE PLOTTED.

| FACTOR | R | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| CONTROL VALUES | 1 | 114 | 113 | 113 | 115 |


Y = DUMMY
100.000
80.0000
60.0000
40.0000
20.0000
.0
50
40
30
20
10
0
1
2
3
LEVELS OF X = PHOSPHORUS

PROFILE ANALYSIS, MEANS OF PROFILE CELL PLOTS FOR JOB 2

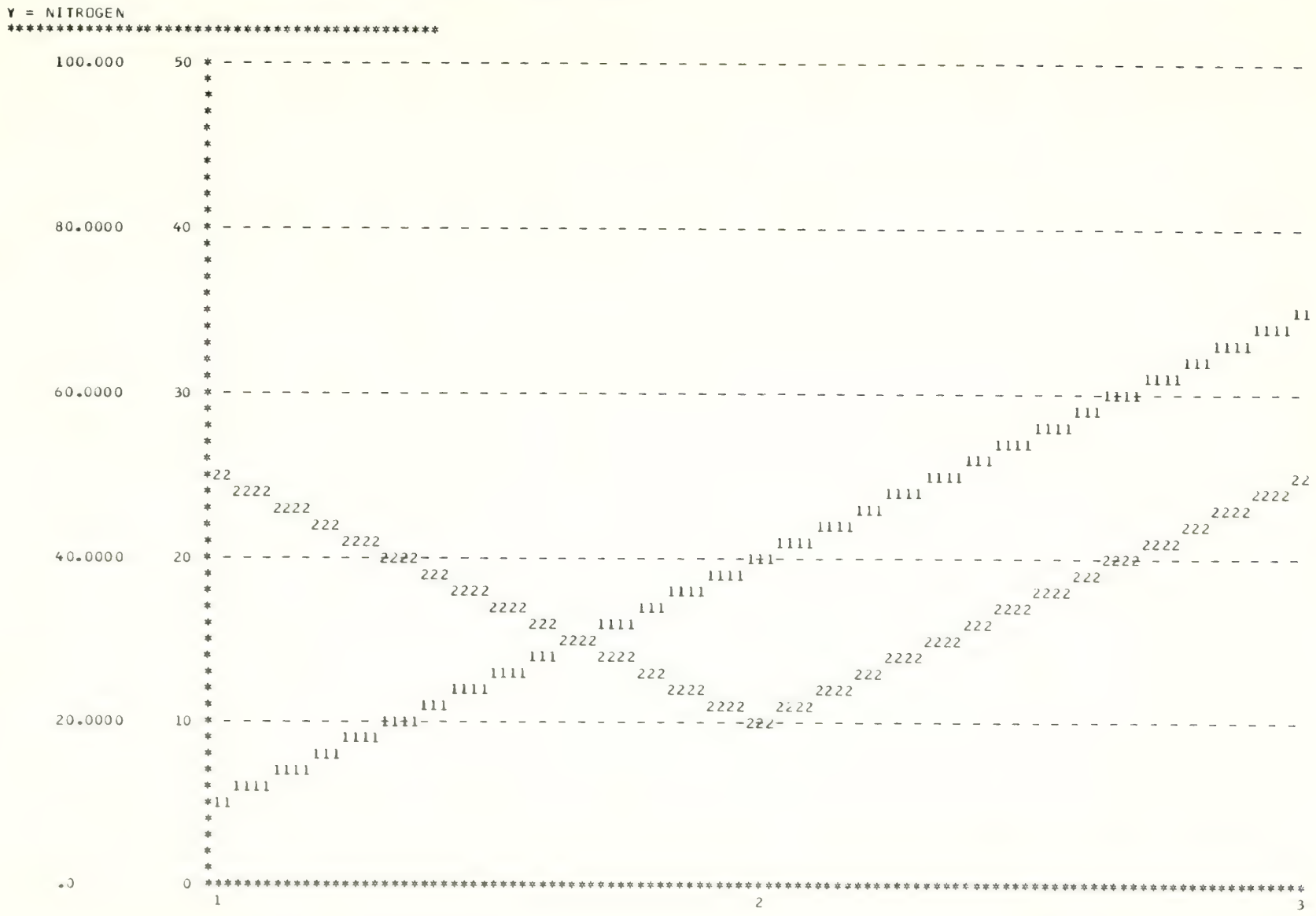
FACTOR LEVELS
0 INDICATES THE LEVELS OF THIS FACTOR ARE TO BE THE LEVELS OF THE X AXIS
* INDICATES THE FACTOR FOR WHICH A SEPARATE PROFILE PLOT IS PRODUCED FOR EACH OF ITS LEVELS.
X INDICATES FACTOR FOR HORIZONTAL AXIS.
Y INDICATES FACTOR FOR VERTICAL AXIS

LEVELS OF X AXIS

| | | | 1 | 2 | 3 |
|---|---|---|---|---|---|
| Y X | | | | | |
| 1 1 1 1 0 1 1 1 1 1 1 | | | | | |
| Y1 -Y12 | MEAN | | 10.00 | 40.00 | 70.00 |
| | NOBS | | 2 | 2 | 2 |
| 1 1 1 2 0 1 1 1 1 1 1 | | | | | |
| Y1 -Y12 | MEAN | | 50.00 | 20.00 | 50.00 |
| | NOBS | | 2 | 2 | 2 |

CONTROL VALUES FOR FACTOR SUBSCRIPTS
113 IMPLIES CELL MEANS ARE SUMMED OVER THIS SUBSCRIPT.
114 LEVELS OF Y AXIS.
115 LEVELS OF X AXIS.
116 PRODUCE A SEPARATE PROFILE PLOT FOR EACH LEVEL OF THIS SUBSCRIPT
1-111 THIS LEVEL OF LTH FACTOR IS TO BE PLOTTED.

| FACTOR | R | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| CONTROL VALUES | 1 | 1 | 113 | 114 | 115 |


Y = NITROGEN
100.000
80.0000
60.0000
40.0000
20.0000
.0
50
40
30
20
10
0
1
2
3
LEVELS OF X = PHOSPHORUS

PROFILE ANALYSIS, MEANS OF PROFILE CELL PLOTS FOR JOB 3

FACTOR LEVELS

0 INDICATES THE LEVELS OF THIS FACTOR ARE TO BE THE LEVELS OF THE X AXIS
* INDICATES THE FACTOR FOR WHICH A SEPARATE PROFILE PLOT IS PRODUCED FOR EACH OF ITS LEVELS.
X INDICATES FACTOR FOR HORIZONTAL AXIS.
Y INDICATES FACTOR FOR VERTICAL AXIS

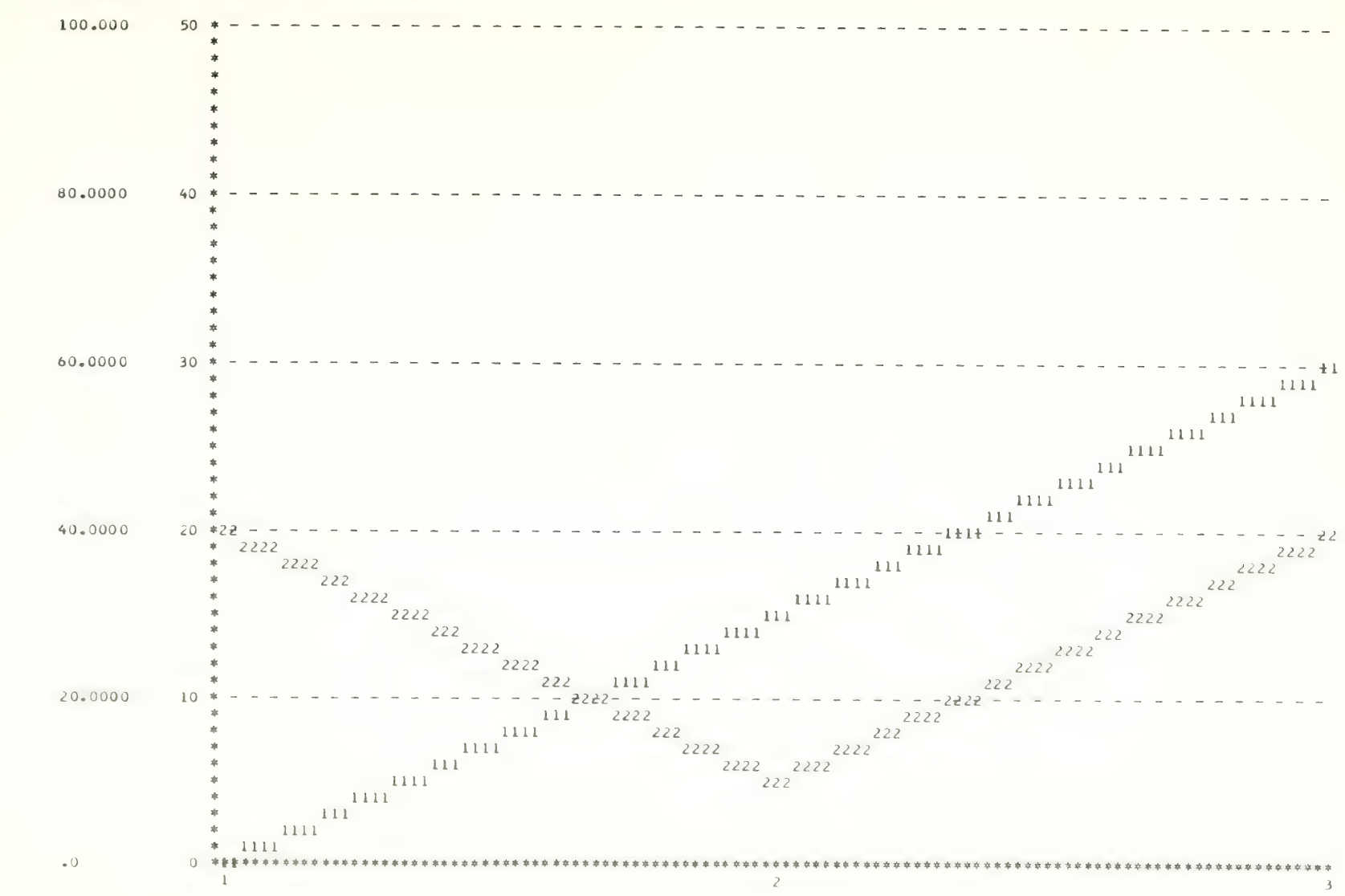
LEVELS OF X AXIS

| | | 1 | 2 | 3 |
|---|---|---|---|---|
| * Y X | | | | |
| 1 1 1 1 0 1 1 1 1 1 1 | | | | |
| Y1 -Y12 | MEAN | 0.0 | 30.00 | 60.00 |
| | NOBS | 1 | 1 | 1 |
| 1 1 1 2 0 1 1 1 1 1 1 | | | | |
| Y1 -Y12 | MEAN | 40.00 | 10.00 | 40.00 |
| | NOBS | 1 | 1 | 1 |

CONTROL VALUES FOR FACTOR SUBSCRIPTS
113 IMPLIES CELL MEANS ARE SUMMED OVER THIS SUBSCRIPT.
114 LEVELS OF Y AXIS.
115 LEVELS OF X AXIS.
116 PRODUCE A SEPARATE PROFILE PLOT FOR EACH LEVEL OF THIS SUBSCRIPT
1-111 THIS LEVEL OF LTH FACTOR IS TO BE PLOTTED.

| FACTOR | R | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| CONTROL VALUES | 1 | 1 | 116 | 114 | 115 |

PROFILE ANALYSIS, JOB= 3  NITROGEN X PHOSPHORUS  EACH SPECIES  TIME 1  SPECIES 1



PROFILE ANALYSIS, MEANS OF PROFILE CELL PLOTS FOR JOB 3

FACTOR LEVELS

0 INDICATES THE LEVELS OF THIS FACTOR ARE TO BE THE LEVELS OF THE X AXIS
* INDICATES THE FACTOR FOR WHICH A SEPARATE PROFILE PLOT IS PRODUCED FOR EACH OF ITS LEVELS.
X INDICATES FACTOR FOR HORIZONTAL AXIS.
Y INDICATES FACTOR FOR VERTICAL AXIS

LEVELS OF X AXIS

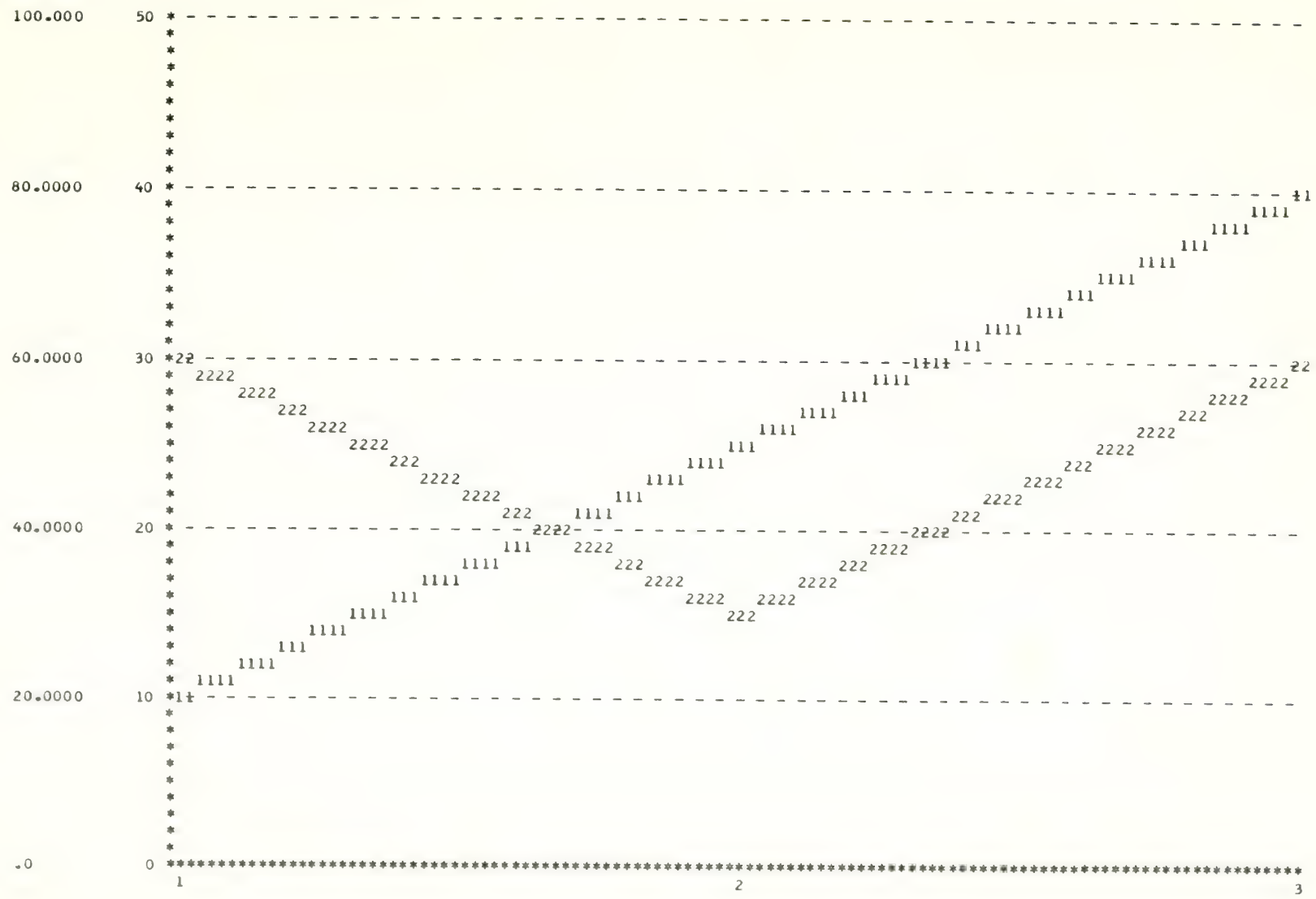
| | | | | 1 | 2 | 3 |
|---|---|---|---|---|---|---|
| * Y X | | | | | | |
| 1 1 2 1 0 1 1 1 1 1 1 1 | | | | | | |
| | Y1 | -Y12 | MEAN | 20.00 | 50.00 | 80.00 |
| | | | NOBS | 1 | 1 | 1 |
| 1 1 2 2 0 1 1 1 1 1 1 1 | | | | | | |
| | Y1 | -Y12 | MEAN | 60.00 | 30.00 | 60.00 |
| | | | NOBS | 1 | 1 | 1 |

CONTROL VALUES FOR FACTOR SUBSCRIPTS
113 IMPLIES CELL MEANS ARE SUMMED OVER THIS SUBSCRIPT.
114 LEVELS OF Y AXIS.
115 LEVELS OF X AXIS.
116 PRODUCE A SEPARATE PROFILE PLOT FOR EACH LEVEL OF THIS SUBSCRIPT
1-111 THIS LEVEL OF LTH FACTOR IS TO BE PLOTTED.

| FACTOR | R | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| CONTROL VALUES | 1 | 1 | 116 | 114 | 115 |

PROFILE ANALYSIS, JOB= 3  NITROGEN X PHOSPHORUS  EACH SPECIES  TIME 1  SPECIES 2

Y = NITROGEN



PROFILE ANALYSIS, MEANS OF PROFILE CELL PLOTS FOR JOB 4

FACTOR LEVELS

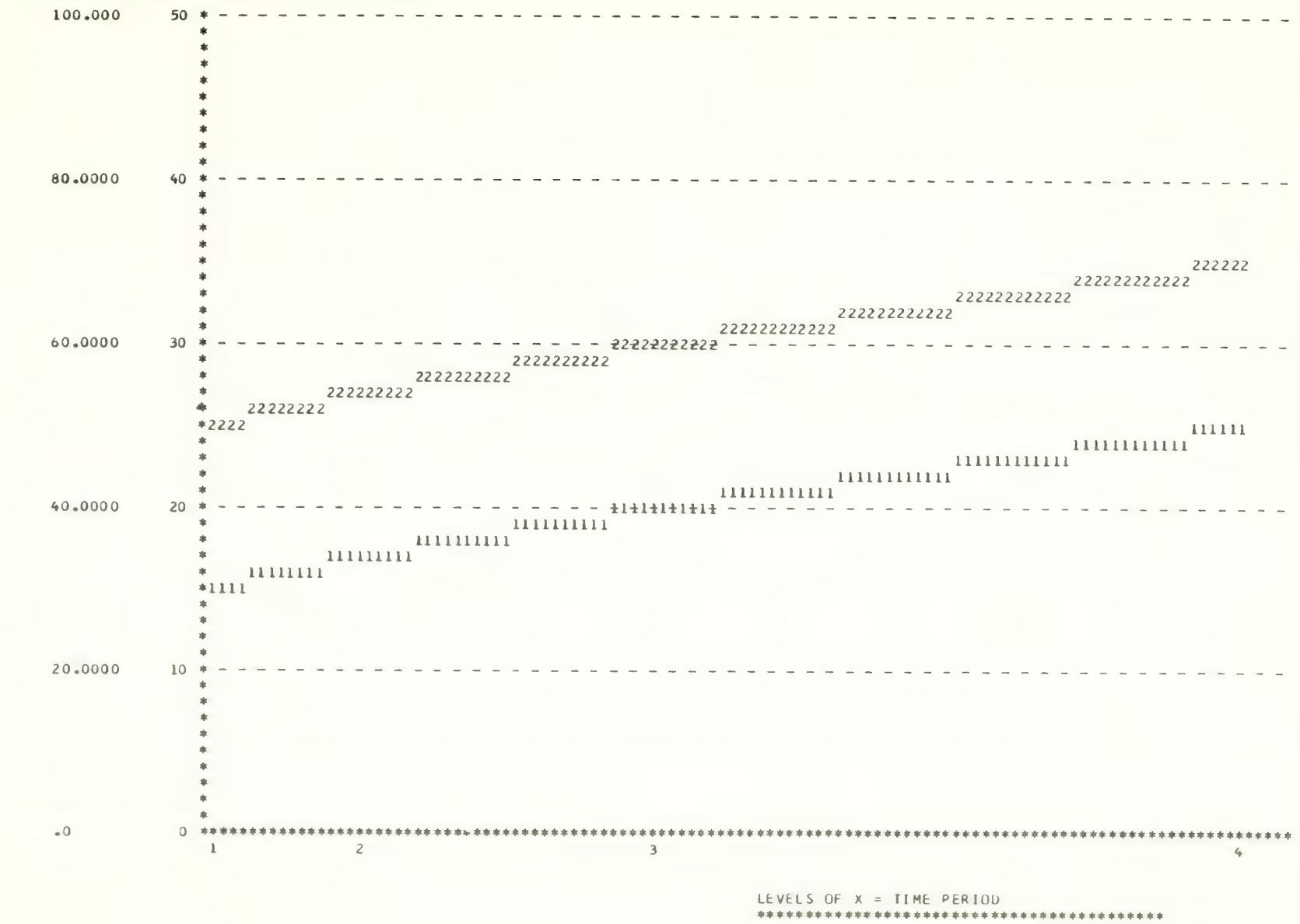
0 INDICATES THE LEVELS OF THIS FACTOR ARE TO BE THE LEVELS OF THE X AXIS
* INDICATES THE FACTOR FOR WHICH A SEPARATE PROFILE PLOT IS PRODUCED FOR EACH OF ITS LEVELS.
X INDICATES FACTOR FOR HORIZONTAL AXIS.
Y INDICATES FACTOR FOR VERTICAL AXIS

LEVELS OF X AXIS

| X | Y | | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| 0 | 1 1 1 1 1 1 1 1 1 1 | Y1 -Y12 | MEAN | 30.00 | 35.00 | 40.00 | 50.00 |
| | | | NOBS | 6 | 6 | 6 | 6 |
| 0 | 1 2 1 1 1 1 1 1 1 1 | Y1 -Y12 | MEAN | 50.00 | 55.00 | 60.00 | 70.00 |
| | | | NOBS | 6 | 6 | 6 | 6 |

CONTROL VALUES FOR FACTOR SUBSCRIPTS
113 IMPLIES CELL MEANS ARE SUMMED OVER THIS SUBSCRIPT.
114 LEVELS OF Y AXIS.
115 LEVELS OF X AXIS.
116 PRODUCE A SEPARATE PROFILE PLOT FOR EACH LEVEL OF THIS SUBSCRIPT
1-111 THIS LEVEL OF LTH FACTOR IS TO BE PLOTTED.

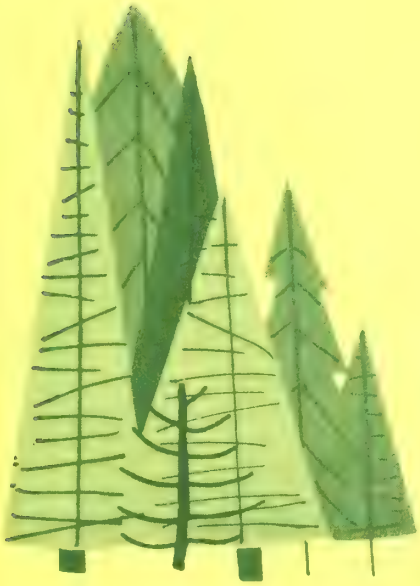
| FACTOR | R | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| CONTROL VALUES | 115 | 1 | 114 | 113 | 113 |


Y = SPECIES
100.000
50
80.0000
40
60.0000
30
40.0000
20
20.0000
10
.0
0
1
2
3
4
LEVELS OF X = TIME PERIOD

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

# Measuring Perception of Elements in Outdoor Environments

by George H. Moeller
Robert MacLachlan
and Douglas A. Morrison



USDA FOREST SERVICE RESEARCH PAPER NE-289
1974

NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

## THE AUTHORS

GEORGE H. MOELLER received his undergraduate and graduate degrees in forestry from Southern Illinois University. He is currently a project leader with the USDA Forest Service recreation research unit maintained at Syracuse, N. Y., by the Northeastern Forest Experiment Station in cooperation with the State University of New York College of Environmental Science and Forestry. His present research assignment is to develop models to forecast the quantitative and qualitative aspects of outdoor recreation participation.

ROBERT MacLACHLAN received his master's degree at the State University of New York College of Environmental Science and Forestry. He is currently engaged in therapeutic recreation programming.

DOUGLAS A. MORRISON holds a Ph.D. degree in resource management from the University of Oregon. He is currently a research associate and assistant professor with the School of Environmental and Resource Management, State University of New York College of Environmental Science and Forestry, Syracuse, New York.

MANUSCRIPT RECEIVED FOR PUBLICATION 12 NOVEMBER 1973

# Measuring Perception of Elements in Outdoor Environments


## ABSTRACT

The meanings of 10 concepts that describe elements of natural outdoor environments were measured with the semantic differential technique. Each concept was evaluated on three factors of meaning — evaluation, potency, and activity. Sixty recreationists were surveyed from each of three user groups — campers, picnickers, and wilderness hikers. Similarities and differences were found in the way in which the groups perceived each other and elements of recreation environments. Study results should contribute toward a better understanding of the way in which people relate to outdoor environments and what they expect from those environments.

SOME OF THE MOST challenging questions that resource planners and managers need answers to are: What do natural environments *mean* to people who use elements of those environments? How do these people perceive one another? And how do they relate to people who manage natural environments? The solution to these questions lies at the core of understanding how people relate to natural environments and what they expect from those environments. As Leopold pointed out in his *Sand County Almanac* (*1966*), "to promote perception (of nature) is the only truly creative part of recreational engineering."

The purpose of this study was to quantitatively describe how three groups of recreationists—auto campers, wilderness hikers, and picnickers—responded to these questions.

## PERCEPTION AS MEANING

The scientific investigation of how people perceive natural environments, other people who use those environments, and resource managers is important to the resource-management process. Research approaches such as those by Lucas (*1964*), Wenger and Videback (*1969*), Hendee et al (*1968*), Shafer et al (*1969*), and Sonnenfeld (*1969*) have set the stage for continued research in this field. But the human perceptual process is still not understood. Osgood et al (*1967*) state that, even among psychologists, there is much confusion about what constitutes perception.

In our study, *perception* was considered to be synonomous with *meaning*. Perception and meaning are intimately related, as demonstrated by the following discussion on perception found in the *Dictionary of Philosophy and Psychology* (*Baldwin 1960*):

> Perception is sensation only insofar as sensation conveys meaning. I perceive a tree that grows before my window; there is here an object which is perceived and an act of mind by which it is perceived. The object is made up of a trunk, branches, and leaves; but the act of the mind by which it is perceived has neither trunk, branches or leaves. I find nothing that resembles it so much as the remembrance of a tree, or the imagination of it.

It is this "act of the mind" that is ultimately important to the recreation experience. A wilderness hiker who imagines the expected

view from a mountain top may be spurred up the arduous mountain trail. Families spend weeks elaborately planning vacations and thereby enjoy a considerable portion of their vacation experience even before it occurs. The importance of memory and recall to total enjoyment of a recreation experience is adequately demonstrated by the universal inclusion of the camera as part of one's standard recreation gear and by the stories recreationists tell after they return from outdoor experiences.

Meaning may be denotative or connotative. Denotative meaning always specifies something to which one can point (e. g., a pencil). In contrast, connotative meaning is emotional, expresses a value or preference, and varies from person to person (e. g., wilderness). Our study was concerned with measuring the connotative meaning of general concepts that relate to natural recreation environments, managers, and recreationists.

## PROCEDURE

The semantic differential technique, as developed by Osgood, was used in this study to measure the meanings of various concepts related to recreation experiences in natural environments. Osgood used factor analysis of 50 bi-polar adjective pairs to isolate three major factors or "dimensions" of meaning: *evaluation, potency, and activity*. The three factors can best be described by the adjective pairs that were most highly associated with them.

Osgood found that the adjective pairs most highly associated with the evaluation factor were: good-bad, beautiful-ugly, sweet-sour, clean-dirty, tasty-distasteful, valuable-worthless, kind-cruel, pleasant-unpleasant, sweet-bitter, happy-sad, sacred-profane, nice-awful, fragrant-foul, honest-dishonest, and fair-unfair. The nature of the potency factor was best defined by the adjective pairs: large-small, strong-weak, heavy-light, and thick-thin. The most distinct scales associated with the activity factor were: fast-slow, active-passive, and hot-cold.

Osgood pointed out that the three factors do not completely delineate the semantic space because they accounted for only up to 50 percent of the total variance in the meaning of general concepts. He also found that the nature and magnitude of the factors varied with the concepts judged. His studies frequently showed variability in factor structures; often factors combined or did not appear consistently. Nevertheless, Osgood concluded that, "the existence of a large number of dimensions to the total semantic space is not disastrous as far as measurement is concerned"; this is because any additional factors account for a relatively small proportion of the total variance regardless of the concept studied.

### The Concepts and Test Instrument

Ten general concepts were selected to describe major elements of recreation experiences and environments. The natural environment was represented by six concepts: national forest, wilderness, state park, lake, mountain, and wildlife. Concepts that represented recreationists were the three groups sampled in the study—auto camper, wilderness hiker, and picnicker. The recreation resource manager was represented by park ranger.

The 10 concepts are very general and do not describe specific aspects of recreation experiences and environments. Therefore results must be interpreted broadly and not related to specific situations. Once the technique has been more fully tested, studies can be undertaken to answer particular questions.

As Osgood pointed out, adjective pairs that have maximum loadings on one factor and minimum loadings on another factor should be used to construct a semantic differential test instrument. It would be most desirable to use one specific scale to represent each factor; however, individual scales are neither perfectly aligned with factors nor perfectly reliable. Therefore Osgood suggested that a small number of closely related scales be used to represent each factor and that an average factor score be derived from them.

The average factor score is assumed to be more representative and more reliable than factor scores that could be derived from indi-

vidual scales. Twelve bi-polar adjective pairs were selected from Osgood's results and used to construct the test instrument for this study. Three sets of four bi-polar adjective pairs—one set for each of the three factors—were selected to measure the meaning of the 10 concepts (table 1).

*Table 1.—Bi-polar adjective scales and associated factor loadings*[a]

| Bi-polar adjective scale | Scale factor loading | | |
|---|---|---|---|
| | Evaluation (E) | Potency (P) | Activity (A) |
| Honest-dishonest | .85 | .07 | —.02 |
| Pleasant-unpleasant | .82 | —.05 | .28 |
| Valuable-worthless | .79 | .04 | .13 |
| Relaxed-tense | .55 | .12 | —.37 |
| Large-small | .06 | .62 | .34 |
| Strong-weak | .19 | .62 | .20 |
| Rugged-delicate | —.42 | .60 | .26 |
| Wide-narrow | .26 | .41 | —.07 |
| Fast-slow | .01 | .00 | .70 |
| Active-passive | .14 | .04 | .59 |
| Hot-cold | —.04 | —.06 | .46 |
| Ferocious-peaceful[b] | —.69 | .17 | .41 |

[a]Scales and factor loadings were take directly from Osgood, *et al*, The Measurement of Meaning, p. 37. Underlines indicate the factor that each adjective scale was used to represent in the present study.

[b]Heavily loaded on both the evaluation and activity scales.

The 12 adjective pairs were arranged randomly on individual sheets for each concept. Sheets were assembled into a 10-page test booklet. Respondents were asked to check one of seven scale positions for each bi-polar adjective scale. The position checked indicated how a respondent felt an adjective pair best described his feeling about a particular concept. The seven scale positions ranged from high (very pleasant) through neutral to low (very unpleasant).

## Sampling Procedure

Recreationists were sampled at three areas: auto campers from campgrounds along the Allegheny Reservoir in northwestern Pennsylvania; wilderness hikers from the Adirondack Mountains of northern New York State; and picnickers from Chittenango Falls State Park in central New York State.

The Allegheny Reservoir lies almost entirely within the Allegheny National Forest. Recreation use patterns are influenced strongly by modern campground facilities and related water-oriented recreation developments. Paved parking spurs, flush toilets, hot showers, and sewage-disposal stations attract campers with elaborate motordrawn camping equipment.

Auto campers were randomly selected from three developed campgrounds. Interviews were divided among campgrounds in proportion to their occupancy rate on a sampling day. A fixed-interval sampling procedure was used within campgrounds. If campers were not at their sites, repeat visits were made until they could be contacted. If two or more camper groups occupied a selected site, a random procedure was used to select the respondents.

The Mt. Marcy Wilderness lies in what is commonly called the High Peaks Region of the Adirondack Mountains of New York State. The primary attraction of the area is its wilderness character. Recreation use patterns are strongly governed by the lack of developed facilities.

Because wilderness hikers are usually busy making or breaking camp, cooking meals, and planning the next day's activities, interviews were conducted along hiking trails between 10:00 a.m. and 4:00 p.m. Estimates of the total number of visitors were not available; therefore sampling precision could not be specified. Interviews were conducted with every fifth wilderness hiker group encountered. Only those who had stayed in the area for at least one night were asked to take part in the study.

Chittenango Falls State Park is located midway between the Villages of Chittenango and Cazenovia in central New York State. The major park attraction is a 167-foot waterfall. Facilities include picnic tables, charcoal grills, swings, sand boxes, and play fields. Picnicking and viewing the waterfall are the major recreation activities.

Fifteen picnickers were interviewed on each of four sampling days at Chittenango Falls State Park. On each sample day, an estimate

was made of the number of families picnicking in the area, and respondents were selected by proportional random sampling from a list of occupied picnic tables.

Sixty interviews were conducted for each of the three recreationist groups. No campers or picnickers refused to participate in the study. Two wilderness hikers declined to be interviewed because of lack of time.

Sampling was conducted on weekends in August and September 1969. Only heads of recreationist groups were interviewed. The sampling procedure was subject to problems commonly encountered in sampling recreationists. For example, accurate use estimates could not be determined for wilderness hikers. The procedure may also be biased by length of stay because recreationists who stayed longer at a particular area were more likely to be included in the study. No attempt was made to evaluate the sources of bias inherent in the sampling procedure or to weight responses.

Interviewers outlined the study objectives and explained the procedure to be used in filling out test booklets. If problems in interpretation arose, the interviewer explained that he was interested in the respondent's own evaluation, even though a particular adjective pair did not seem to relate directly to the concept.

The groups were not entirely mutually exclusive. For example, campers had undoubtedly picnicked and hiked sometime in the past. The way in which this may have biased the study results cannot be determined precisely; however, it can be expected that this would reduce the variations in response between groups.

## ANALYSIS

### Scoring the Semantic Differential

The methods used to score the semantic differential test instrument and analyze data follow procedures outlined by Osgood. The seven ordinal-scale positions were assigned interval values ranging from −3 (very unpleasant) through 0 (neutral) to +3 (very pleasant). In this way, for each adjective pair, a numerical score was obtained for each respondent on each concept. An individual's factor score for a concept was calculated by averaging the four adjective-pair scores for that factor. With this procedure, 30 factor scores were calculated for each respondent—one score on each of the three factors for each of the 10 concepts. Mean factor scores on all concepts were calculated by averaging the individual respondent factor scores by recreationist group.

### Differences Between Groups

Simultaneous chi-square statistical tests were used to determine if the distribution of factor scores on each of the 10 concepts was the same between groups (table 2). Statistically significant differences were found between groups for 1 or more factors on 7 of the 10 concepts studied (figure 1).

Table 2.—*Example chi-square test procedure used to determine statistically significant differences in distribution of factor scores between recreation user groups*

| Recreationist group | Distribution of individual factor scores[a] Concept: "Wilderness"—Factor: "Evaluation" | | | |
|---|---|---|---|---|
| | 0 to .50 | .51 to 1.49 | 1.50 to 2.49 | 2.50 to 3.00 |
| Auto campers | 10 | 18 | 21 | 11 |
| Wilderness hikers | 0 | 13 | 28 | 19 |
| Picnickers | 4 | 18 | 24 | 14 |

$X^2 = 15.1$, significant at .05 level.
[a]The contingency scale was expanded when negative factor scores were encountered.

Whenever chi-square tests revealed a difference in the distribution between the three groups, paired chi-square tests were used to test for differences in response distribution between any two of the three groups (table 3). Paired tests showed statistically significant factor score differences on six of the seven concepts for which differences had been found using the three-way tests.

Moeller, George H., Robert MacLachlan, and Douglas A. Morrison. 1974. **Measuring perception of elements in outdoor environments.** NE. Forest Exp. Sta., Upper Darby, Pa.
9 p., illus. (USDA Forest Serv. Res. Pap. NE-289)

The meanings of 10 general concepts that describe elements of natural outdoor environments and experiences were measured with the semantic differential technique. Each element or concept was evaluated in terms of semantic scores on three factors of meaning—evaluation, potency, and activity. A total of 180 recreationists were surveyed—60 from each of three recreation groups. Similarities and differences were found among the three groups—campers, picnickers, and wilderness hikers—in the way in which they perceived each other and elements of recreation environments. Although they are tentative, study results should contribute toward a better understanding of the way in which people relate to outdoor environments and what they expect from those environments.

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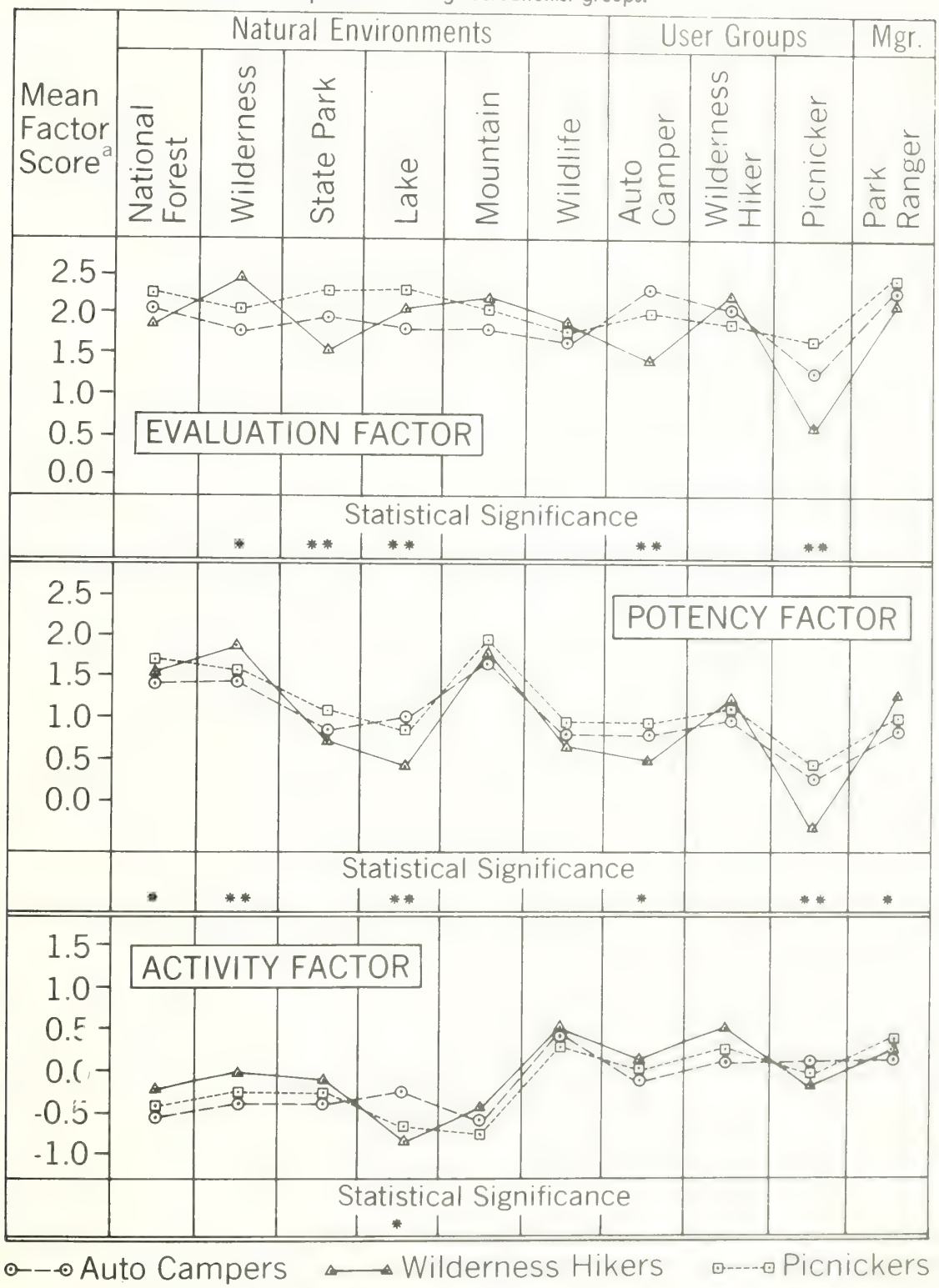
Figure 1.—Mean factor score data profiles and chi-square test results for comparisons among recreationist groups.




[a]Mean factor scores theoretically range from +3 to −3.
*Significant difference at .05 level.
**Significant difference at .01 level.

Table 3.—*Results of paired chi-square tests for comparisons of user group response scores*

| Concept | Recreation user groups[b] being compared | Factor[c] | | |
|---|---|---|---|---|
| | | Evaluation | Potency | Activity |
| Natural environments:[a] | | | | |
| National forest | AC vs. WH | NT | * | NT |
| | WH vs. P | NT | * | NT |
| | AC vs. P | NT | ND | NT |
| Wilderness | AC vs. WH | ** | ND | NT |
| | WH vs. P | ND | * | NT |
| | AC vs. P | ND | ND | NT |
| State park | AC vs. WH | ND | NT | NT |
| | WH vs. P | ** | NT | NT |
| | AC vs. P | * | NT | NT |
| Lakes | AC vs. WH | ND | ** | * |
| | WH vs. P | ND | ND | ND |
| | AC vs. P | ND | ND | ** |
| Other user groups: | | | | |
| Auto camper | AC vs. WH | ** | ND | NT |
| | WH vs. P | ** | ND | NT |
| | AC vs. P | ND | ND | NT |
| Picnicker | AC vs. WH | ND | ** | NT |
| | WH vs. P | ** | ** | NT |
| | AC vs. P | ND | ND | NT |
| Resource manager: | | | | |
| Park ranger | AC vs. WH | NT | ND | NT |
| | WH vs. P | NT | ND | NT |
| | AC vs. P | NT | ND | NT |

[a]Paired tests were conducted only for those concepts in Figure 1 for which significant differences were found among the three groups using the three-way chi-square test.
[b]AC indicates auto campers; WH indicates wilderness hikers; P indicates picnickers.
[c]* indicates significant difference between two groups at .05 level.
** indicates significant difference between two groups at .01 level.
NT indicates no test, because significant difference was not found using the three-way chi-square test (Fig. 1).
ND indicates no difference between the two groups.

# RESULTS AND DISCUSSION

## Perception of Natural Environments

As would be expected, study results suggested that the natural environment, taken as a wholistic entity, is viewed favorably by all recreationists. The three groups perceived the natural environment concepts—National Forest, Wilderness, State Park, Lake, Mountain, and Wildlife—as very valuable, moderately potent, and slightly inactive. Wildlife was perceived as slightly active rather than inactive (fig. 1).

Each group perceived its own recreation environment as being more valuable than other groups perceived it. For example, wilderness hikers rated Wilderness significantly more valuable than auto campers or picnickers did. Picknickers rated State Park as significantly more valuable than either of the other groups rated the concept, and both picnickers and auto campers rated National Forest as more valuable than wilderness hikers did (fig. 1).

*National Forest.*—The concept National Forest was perceived as very valuable, slightly potent, and slightly inactive. The meaning of National Forest was consistent across groups except on the potency factor. National Forest was perceived as being significantly less potent (strong, large, rugged, and wide) by auto campers than by wilderness hikers.

Although the reasons for this are obscure, it is plausible that auto campers may feel that they have tamed the potency of the forest. Hot showers, flush toilets, and their elaborate camping vehicles enable auto campers to enjoy the forest in comfort. Recreation activities are centered within the campground, and social activity seems to be a major motivation among auto campers.

If auto campers had rated the forest as potent, they would have negated the value of their expensive motor-drawn recreation equipment. Wilderness hikers, in contrast, carry their equipment and seek to enjoy the "potent" forest in its primitive state. Picnickers' perception of the potent National Forest may be due to limited exposure to natural forest surroundings and lack of equipment with which to conquer the "potent" forest (table 3).

*Wilderness.*—Like National Forest, Wilderness was perceived as being quite valuable, slightly potent, and slightly inactive. As a group, wilderness hikers perceived Wilderness as being more valuable, more potent, and less active than National Forest.

Wilderness was rated significantly more valuable by wilderness hikers than by auto campers (table 3). It would not have been consistent for wilderness hikers to score Wilderness low on the evaluation factor and at the same time undertake the strenuous activities necessary to enjoy a wilderness experience.

Wilderness hikers rated Wilderness as significantly more potent than picnickers rated it (fig. 1). This result supports the notion that wilderness hikers may feel challenged by the potent natural forces of the wilderness and take pride in pitting themselves against those forces. Results further suggest that Wilderness is perceived as more exacting in terms of site requirements than other kinds of recreation environments.

*State Park.*—As with the other five concepts related to natural environments, State Park was seen as quite valuable. Except by picnickers, State Park was perceived as being slightly potent. All user groups perceived the concept State Park as being slightly inactive (fig. 1).

State Park was significantly more valuable to picnickers than to either of the other groups (table 3). Wilderness hikers scored State Park comparatively low on the evaluation factor, conceivably because they associate such parks with crowded campgrounds and picnic areas in an environment dominated by man—areas that are much less exacting than wilderness in their site requirements.

*Lake.*—The concept Lake was perceived as the second most valuable concept and as the least potent among the six natural environment concepts. Lakes were also perceived as slightly inactive. (fig. 1).

Auto campers perceived the concept Lake as being significantly more potent than wilderness hikers did and as significantly more active than the other two groups did (table 3). These findings, though puzzling at first, can be explained logically. Campers seldom spend all their time camping or viewing scenery, but spend much of their time participating in water-oriented activities. Therefore campers are likely to perceive a lake as being more active than wilderness hikers, who perceive wilderness lakes as serene, or picnickers, who less often experience lake-oriented recreation.

*Mountain.*—No significant differences were found in the way in which the three groups perceived the concept Mountain. Mountain was perceived by all groups as being quite valuable. Of the six concepts used to describe the natural environment, mountain was perceived as being the most potent and least active (fig. 1).

*Wildlife.*—No differences were found between the groups in the meaning of the concept Wildlife. Although perceived as being quite valuable, the concept was seen as the least valuable of the environmental concepts. It was rated low on the potency factor and was perceived as being the most active of all ten concepts, including the recreationists themselves (fig. 1).

Do different recreationists perceive natural environments in the same way? This question cannot be answered simply, but the foregoing discussion suggests that perception of elements in the natural surroundings depends on the kind of experience a particular recreationist group is seeking and the way in which elements of the natural surroundings enhance or detract from their experiences. Of the six concepts, only Mountain and Wildlife were perceived as being essentially the same by all groups.

### Perception of Other Recreation Groups

Respondents were asked to rate three concepts—Camper, Wilderness Hiker, and Picnicker—to determine how they perceived their own group, as well as each of the other groups. With a few important exceptions, recreationists perceived themselves as being less valuable and less potent but more active than concepts related to natural environments (fig. 1).

*Auto Camper.*—All groups perceived the concept Auto Camper as being from slightly to quite valuable. Wilderness hikers perceived auto campers as significantly less valuable than themselves. Picnickers perceived auto campers as significantly more valuable than wilderness hikers did. Although the three-way chi-square test showed a significant difference in the potency factor ratings for Auto Camper, paired tests did not. Auto Camper was rated as neither active nor inactive. Auto campers saw their own group as significantly more valuable, but less potent and less active than they perceived wilderness hikers to be.

*Wilderness Hiker.*—All groups rated wilderness hikers as quite valuable, slightly potent, and slightly active. Wilderness hikers saw themselves as slightly more valuable and active than the other groups saw them (fig. 1). However, no significant differences were found in factor ratings for the concept. Of the three groups, wilderness hikers were seen in a consistently favorable way, not only by themselves, but by other groups as well.

*Picnicker.*—The concept Picnicker, when compared to Wilderness Hiker and Camper, was perceived as less valuable, less potent, and less active. Wilderness hikers rated picnickers as significantly less valuable than picnickers saw themselves. Wilderness hikers rated picnickers lower on potentcy than both picnickers and auto campers rated the concept (table 3).

Surprisingly, picnickers rated each of the other groups higher on all three factors than they rated themselves. In his study of recreationists in the Quetico-Superior Wilderness, Lucas *(1964)* discovered a one-way resentment against boaters by paddling canoeists. Results of our study suggest the existence of a one-way resentment against picnickers by wilderness hikers. Lucas also found that motoring canoeists preferred meeting paddling canoeists rather than their fellow motoring canoeists. Likewise, the picnickers interviewed in our study seemed to look more favorably upon both auto campers and wilderness hikers than on their fellow picnickers. The relatively low rating of picnickers by the three recreation groups may be due to the fact that the concept Picnicker conjures up thoughts of litter and untidyness, by a group of recreationists who are highly transient and are not viewed as a permanent part of natural recreation environments.

Could it be that the image of a recreation group is not determined by the nature of the activity or its influence on the natural environment, but by commonly recognized characteristics of the group? Socio-economic background data collected in our study suggest that this is not true. Wilderness hikers—the group with the most positive image—had more education and earned more money than either auto campers or picnickers. Picnickers, however, had more education and earned more money than auto campers, but were viewed in a relatively negative way. Thus, the image of a recreation group is apparently not determined as much by recognized characteristics of the group as by commonly held feelings about the nature of the activity in which the group is participating.

### Perception of Recreation Managers

*Park Ranger.*—Managers of recreation environments were represented by the concept Park Ranger. Although the concept was rated significantly different on the potency factor when responses of the three groups were compared (fig. 1), paired chi-square tests showed no differences (table 3). The meaning of Park Ranger was consistent for all three groups. The concept appears to mean the same thing as Wilderness Hiker. But the wilderness hiker is seen as slightly more active and a little less valuable.

Do different groups of recreationists perceive each other in different ways? Study results indicate that not only do different

groups perceive other groups differently, but they also see themselves as "different". This result should be carefully considered in developing recreation resources that are intended to meet the needs of several groups at one time. More diversity and physical separation of groups would seem desirable where feelings of animosity exist; however, the exact magnitude and direction of feelings between groups should be more fully investigated before management prescriptions are issued.

Study results suggest that participation in a certain recreation activity conveys a particular group image. Some activities project a more positive or desirable image than others. Activities that require considerable physical effort, such as hiking a wilderness trail, seem to convey a positive image, while activities that involve mechanized travel and little physical effort seem to convey a negative image. Similarly, activities that require a minimum disruption to the natural environment in terms of permanence and facility requirements seem to project a favorable image.

## CONCLUSIONS

This study demonstrated the use of the semantic differential technique to measure the meaning of various elements that influence perception of natural environments and experiences. However, results are tentative. The semantic differential technique must be tested more rigorously in carefully controlled situations before results can be applied to specific management or policy decisions.

The three general factors—evaluation, potency, and activity—should be defined more precisely, using sets of adjective pairs that relate more specifically to environmental concepts. Also, the concepts or elements of concern need to be defined more precisely. In our study, very general concepts were considered to demonstrate the approach. Future research should include base-line concepts—concepts that people clearly understand—the meanings of which are already understood.

Study results do show the usefulness of the semantic differential as a tool for studying the complex process of environmental perception. Some of the more important and immediate questions that could be approached through use of the technique are:

How do people who use elements of natural environments perceive alternative management programs and policies? How do different interest groups perceive environmental issues? How compatible are the goals and expectations of various natural resource users?

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